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PETROLEUM GEOLOGY OF GONDWANA ROCKS OF SOUTHERN BRAZIL[1]

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ABSTRACT

This paper is a condensed version of a study made for the Brazilian Government and published as *Boletim 5*, "Rochas Gondwanicas e Geologia do Petroleo do Brasil Meridional," of the Serviço de Fomento da Producção Mineral of the Departamento Nacional da Producção Mineral, Ministry of Agriculture. (Many well logs and analyses not given in the present paper may be found in the Portuguese bulletin.)

It represents the results of a very extensive geological field study of Southern Brazil, and covers the states of São Paulo, Paraná, Santa Catharina, and Rio Grande do Sul.

The logs and locations of more than seventy borings drilled in this area were for the first time carefully analyzed and located on the accompanying map.

The existing bibliography was duly considered, as well as the writer's previous studies and knowledge of the Gondwana rocks of several South American countries.

The paper gives a new interpretation of the structural characteristics of the Paraná Basin, and sets forth many new geological observations and facts, besides making a close correlation with the known Gondwana rocks of other continents.

The stratigraphy of the Santa Catharina system of Southern Brazil has been slightly modified in accordance with the most recent data. The geological analysis of this part of Brazil, as correlated with systems of Gondwana rocks known in many other continents and countries, permits certain positive conclusions regarding the petroleum geology of Southern Brazil.

The many geological cross sections of Southern Brazil and neighboring countries (drawn for the first time) clearly demonstrate the structural character of the basin and its relationship with any oil accumulations, if such exist.

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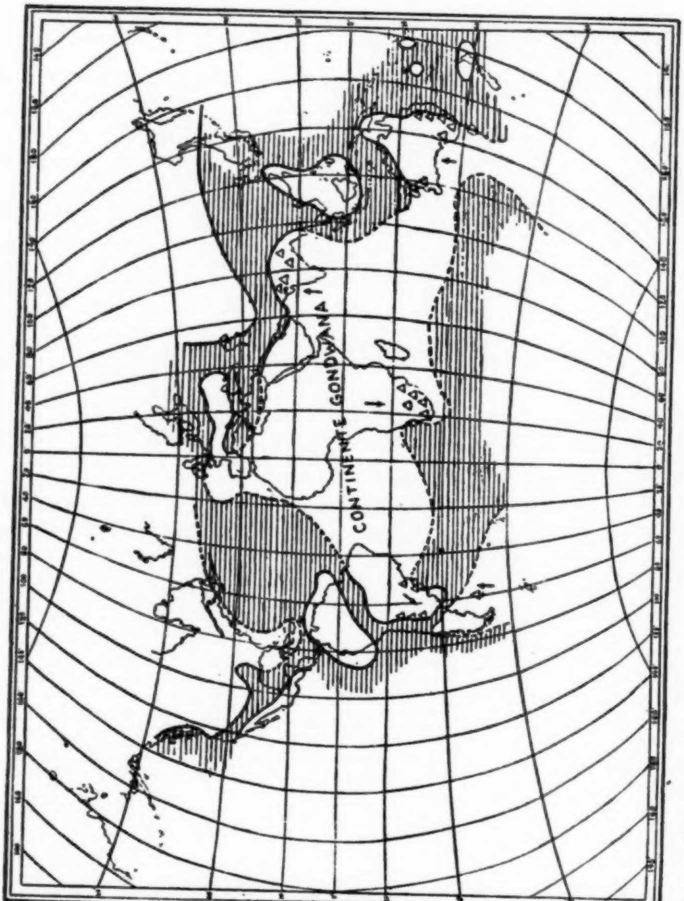


FIG. 1.—Paleogeographic sketch of probable extension of Gondwana continent in Southern Hemisphere and India at beginning of Permian age. Arrows indicate movements of ice sheets, and triangles remains of glaciation.

Part I

Gondwana Rocks of Southern Brazil

I. GONDWANA SYSTEM

The continental masses of the Southern Hemisphere began to appear as one more or less united continent in early Paleozoic time. They are observable as connected lands through half of the Mesozoic age, and their development culminated at the end of the Triassic.

The surprising uniformity of stratigraphic and, in part, paleogeographic conditions through widely separated areas, leads us to apply the conception of the Gondwana system to the geological areas of the Antarctic, Australia, Tasmania, New Zealand, India, Madagascar, South Africa, Central and West Africa, Patagonia, Falkland Islands, West and East Argentina, Southeast Bolivia, Paraguay, Uruguay, and Southern Brazil.

The Gondwana system is everywhere characterized by the great development of terrestrial sediments, marine transgressions being few and sporadic.

The two outstanding features of the Gondwana system are the *Glossopteris* flora and the early Permian glaciation in the Southern Hemisphere. These characteristics are invariably present in the dispersed fragments of the ancient Gondwana continent.

The glaciation which marked the beginning of sedimentation of the Gondwana system assumed proportions greater than any of the climatic phenomena known in the earth's history.

The Gondwana rocks show considerable development in Southern Brazil. The base of the system rests visibly and almost entirely on Algonkian and Archean formations, the exception occurring in part of the State of Paraná, where they rest on Devonian rocks. The considerable stratigraphic hiatus at the base of the system is consequently evident.

In the present article it is proposed to consider only the sedimentary basin, which is limited on the east by the Archean complex of the Serra do Mar or by the metamorphic formations (Minas and Assunguy series), and on the south and west by the extensive basaltic traps forming the Serra Geral.

A comparative study of the stratigraphic columns, from the first, established by I. C. White, to our own field observations, leads us to adopt the column as presented in Table I.

II. GLACIAL SEDIMENTS (ITARARÉ SERIES)

Geographic distribution.—The base of the Gondwana system in Southern Brazil is formed by a glacial sedimentary series of consider-

TABLE I

STRATIGRAPHIC COLUMN OF GONDWANA SYSTEM OF SOUTHERN BRAZIL

	Quaternary Tertiary Cretaceous		Post-Gondwana sediments	CENOZOIC
			Unconformity	
GONDWANA OF PARANÁ BASIN SANTA CATHARINA SYSTEM			Caiuá sandstones (in São Paulo)	MESOZOIC
	Rhaetic	SÃO BENTO SERIES	Serra Geral traps	
			Botucatú sandstones	
			Local Unconformity	
	Upper Triassic		Rio do Rasto group: sandstones, red, and variegated clays. (Saurian remains at Santa Maria)	
			Unconformity	
	Triassic	PASSA DOIS SERIES	Upper Estrada Nova: yellow, red, and variegated clay-stones and shales Therezina, Rocinha, and Serrinha beds	
			Assumed Unconformity	
	Upper Permian		Lower Estrada Nova: shales and gray sandstones Iraty group: shales and bituminous limestones	PALEOZOIC
		TUBARÃO SERIES	Palermo and Rio Bonito groups: light-colored sandstones and gray shales	
	Lower Permian	ITARARÉ SERIES	Itararé: tillites and glacial sediments	
			Unconformity	
	Devonian		Devonian sediments: Ponta Grossa shales and Furnas sandstones	
			Unconformity	
	Silurian to Archean		Santa Catharina slates	
			Metamorphic rocks of Série de Minas and Série de Assunguy	
			Granites and basement rocks	

able vertical and horizontal development, known as the Itararé series.

Derby (1)[3] was the first to assume a glacial origin for these sediments, and proofs of glaciation were first found by G. B. Woodworth (2) in 1912.

On this continent, glaciation of Southern Brazil was apparently contemporary with that of Eastern and Western Argentina (Sierra of Buenos Aires, Sierras Pampeanas, and pre-Cordillera) (3), Southeast Bolivia (4 and 5) (Mandiyuti and Oquita formations), Uruguay (6 and 7), and Falkland Islands (8). Other continents of Gondwana

[3] Numbers in parentheses refer to Bibliography at end of Part I

origin present evidence of glaciation which probably also occurred at the same time as that of Southern Brazil.

Owing to certain peculiarities, the characteristic remains of glaciation in Southern Brazil are less plentiful than in most of the areas previously mentioned. In spite of this, and although difficulty is experienced in the precise stratigraphic separation of the truly glacial beds of Itararé from the post-glacial sediments of the Tubarão series, owing to the intimate connection between the two, it can be said that the area covered by glacial sediments in Brazil is limited to latitudes between 21° and 31° S. and longitudes between 47° and 51° W., that is, from a little north of Campinas, in the State of São Paulo, to Santo Antonio, on the borders of Uruguay.

The Itararé belt continues up to the south of Tubarão (State of Santa Catharina), where it disappears below the eruptive cover of the Serra Geral. In Rio Grande do Sul, the Itararé appears sporadically in São Jeronymo and Santo Antonio, continuing well developed in Uruguay, where, south of the Rio Negro, it closes the Gondwana sedimentary basin of Paraná. Farther south, and on the eastern coast, the glacial sediments reappear in the Sierras de Buenos Aires, in Argentina. Although contemporary, the sediments of the Falkland Islands are of a somewhat different character.

In the Paraná Basin the Itararé is limited in the east by the metamorphic and Archean rocks of the Serra do Mar and Escudo Riograndense; only in the State of Paraná and in Uruguay does it rest on Devonian rocks (9). It seems to the writer that the northern limit passes through Urutuba, in the State of São Paulo.

The most northerly sediments, observable west of Casa Branca and Mococa, have the characteristics of Neo-Mesozoic fluvial deposits. The boulders are fluvial transport material of an erosion period later than the Itararé beds. In the writer's opinion, these sediments are not directly related to glacial deposition: they probably represent material of secondary sedimentation due to erosion of glacial Itararé beds.

The western limit of Itararé is much less clearly defined, and is constituted by the sediments of the Tubarão series—Bonito and Palermo groups.

Although they have not been observed, it is assumed that there are large transgressions of Neo-Gondwanic rocks above Itararé in the areas of the eruptive traps of the Serra Geral, as shown by the borings at Paso Ulestie, in Uruguay.

Stratigraphy.—Morphologically, the large area of glacial sediments is not distinguishable from the other sediments of the basin. The area

TABLE II
STRATIGRAPHIC COMPARATIVE TABLE OF GONDWANA IN SOUTH AMERICA

European Equivalents	*Southern Brazil (Paraná Basin)* (groups)	*Southern Brazil (Paraná Basin)*	*Republic of Uruguay*	*Southeast Bolivia* (groups)	*Southeast Bolivia*	*Northeast Argentina*	*West Argentina and Patagonia* (groups)	*West Argentina and Patagonia*	*Falkland Isles* (groups)	*Falkland Isles*
		Caiuá sandstones (São Paulo)			Tacurú formation: sandstones and shales		ESTRATO DE LA RIOJA; ESTRATOS DE PAGANZO	Marine transgression of Liassic in the Cordillera and Patagonia		
Rhaetic	SANTA CATHARINA SYSTEM; SÃO BENTO SERIES	Serra Geral traps	Basaltic trap			Areniscas Superiores				
		Botucatú sandstone	Areniscas de Tacuarembó					Rhaetic sediments		
Upper Triassic		Rio do Rasto group with saurian remains	Rio do Rasto (Dept. of Cerro Largo)							
	PASSA DOIS SERIES	Upper Estrada Nova: Therezina, Rocinha and Serrinha beds	Estrada Nova: light and variegated shales		Vitiacuá beds: limestone and chert	Horizonte Calcáreo-dolomitico		Sierras Pampeanas, in Patagonia: red sandstones		
		Lower Estrada Nova: dark shales and sandstones		BERMEJO SERIES	Machareti formation: sandstones and shales	Areniscas Inferiores	ESTRATOS DE UMANGO	Catuna strata (Estratos de Catuna)	LAFONIAN SYSTEM	Sandstones and shales
Upper Permian		Iraty group: shales and limestones	Melo group							Shales and clays
	ITARARÉ TUBARÃO SERIES	Palermo and Rio Bonito groups: sandstones and clays	Palermo group		Mandiyuti conglomerate: fluvio-glacial			Estratos de Jejenes Estratos de Sonda Estratos de Tontal		Sandstones, shales, etc.
Lower Permian		Itararé glacial sediments	Bonito-Itararé glacial sediments		Oquita marino-glacial formation	Glacial sediments		Glacial sediments		Glacial sediments
		Unconformity	*Unconformity*		*Unconformity*	*Unconformity*		*Unconformity*		*Unconformity*

TABLE III

STRATIGRAPHIC COMPARATIVE TABLE OF GONDWANA IN AFRICA, INDIA, AUSTRALIA AND SOUTHERN BRAZIL

Eras	European Equivalents		South Africa (Cape Province)		India (Hindustan)		Australia (New South Wales)	Southern Brazil (Paraná Basin)		
MESOZOIC	Rhaetic	STORMBERG SERIES	Cave sandstone Red beds	MAHADEVA SERIES	Rajmahal			Caiuá sandstone (in São Paulo) Serra Geral traps Botucatú sandstone	SÃO BENTO SERIES	SANTA CATHARINA SYSTEM
	Triassic		Molteno beds	DANCHET SERIES	Parsora	HAWKESBURY SERIES	Wianamatta	Rio do Rasto group		
					Maleri		Hawkesbury sandstones			
			Upper Beaufort		Panchet		Narrabeen	Upper Estrada Nova	PASSA DOIS SERIES	
PALEOZOIC	Upper Permian		Lower Beaufort White band	DAMUDA SERIES	Raniganj		Upper coal seams Dempsey beds	Lower Estrada Nova Iraty group		
			Ecca series		Barakar		Tomago coal seams Greta coal seams	Palermo and Bonito groups	TUBARÃO SERIES	
	Lower Permian	DWYKA SERIES		TALCHIR SERIES	Karhabari					
			Glacial sediments		Talchir		Upper glacial beds	Itararé glacial sediments	ITARARÉ SERIES	

presents a peneplaned, undulating surface without notable topographic relief, even in the eastern and western zones of contact.

The Itararé sediments are composed chiefly of highly heterogeneous sandstones, and vary from coarse conglomeratic tillites to glacial clay and shales.

Irrefutable evidence of the glacial origin of the beds is furnished by the striated or rolled boulders and typically glacial fine clays in association with boulders (tillites). Varve clays were first observed and described by Washburne (10) in São Paulo; these are deposits carried by ice sheets in standing water and are found in successive gray or black beds of a few millimeters up to centimeters in individual thickness, although they may form beds many meters thick, as has been recorded in wells in the State of São Paulo. The deposits of glacial dust, called loessites by Woodworth (2) may be cited as further evidence.

The glacial boulders sporadically disseminated throughout the sedimentary mass are fragments of granites, gneiss, phyllites, quartzites, limestones, diabase, et cetera, and vary in size from grains of a few millimeters to erratic blocks of 1–3 meters in diameter, examples of the latter being found at Campinas. In most outcrops, boulders of 15–30 centimeters in diameter predominate.

In spite of the extensive area of glacial deposits, there are comparatively few boulders with two striated surfaces, such as are typical of boulders from the base of a glacier. There is an abundance of rolled but unstriated tillites of Eo-Paleozoic and Archean rocks, and a notable distribution of limestone, which probably originated from migratory infiltration through the Itararé.

The pigmentation of the sediments varies with different localities and depths, though greenish gray coloration predominates. The coloring may be red, as in the State of São Paulo and in Uruguay, due to ferruginous infiltrations from the overlying eruptives, or even black, which is the color of the shales of the glacial series in Santa Catharina. In deep wells, the Itararé reveals beds of fine white sandstones not observable in the outcrops.

Moraes Rego (11) mentions the following places in the State of São Paulo where the beds are best exposed: the sections north of Campinas; close to Cosmopolis; around Santa Barbara, branch of Piracicaba; between Iracy and Rio das Pedras; the sections beyond Soracaba and the district around Ipanema; in the Itararé River valley. The writer observed that the tillites of Pitanga, west of Rio Claro, are also characteristic.

In Paraná, Eusebio de Oliveira (12) describes in detail typical oc-

currences of sedimentary rocks. In Paraná the Itararé attains its maximum superficial development, and rests above the Devonian sedimentary rocks in a wide belt between São Luiz de Puruná and Faxina, in the State of São Paulo. At the other points of contact, the Itararé rests above the metamorphic or granitic rocks of the Basement complex.

The wells in the State of Paraná have not reached the base of Itararé, with the exception of the recently finished well at São José do Paranapanema, which reached the base at 471 meters and continued through fossiliferous Devonian sediments to a depth of 597 meters. Beds of tillites and successions of varve clays were also recorded at this well.

In the State of Santa Catharina the Itararé is much less developed. It narrows toward the south and ends south of the Tubarão, in the Urussunga River. South of Mafra, the Itararé is characterized by the abundance of tillites, and excellent sections may be seen in the Itajahy River valley and on the Florianopolis-Lages road, where a thickness of 300 meters of Itararé was recorded.

Many of the lower beds, in contact with the granites, are finely textured dark or black shales. Boulders of granite of varying sizes, mica schists, and quartzite are common here, but no varve clays have been observed in these sections.

Farther south, in the Tubarão basin, the measured thickness of the glacial sediments was only 32 meters, including the "Orleans conglomerate" of I. C. White (13).

South of Lauro Muller, erratic blocks of granite are found. These blocks appear to be related to the subjacent granites, and do not show the characteristics of glacial boulders.

In the State of Rio Grande do Sul typical Itararé occurs only sporadically, as in the São Jeronymo well, on the Cacequi road, and in the zone of Santo Antonio. The thicknesses measured in São Jeronymo vary from 1.8 to 16 meters of shales and tillites which rest directly on the crystalline basement. The occurrence at Santo Antonio is also in superficial contact with the basement.

Almost the whole of the western extension of the Escudo Riograndense is bordered by the sediments of the Tubarão series, the latter resting transgressively on the rocks of the complex.

In no part of Southern Brazil did the writer notice surfaces—striated or otherwise—typical of glacial erosion, apart from the granite protuberances near Campinas (São Paulo), which are rounded but not striated.

The thickness of the glacial beds varies considerably; in the State

of Rio Grande do Sul and in the southern part of Santa Catharina the beds are shallow.

None of the wells in the State of São Paulo has so far reached the crystalline basement of the Itararé. According to Washburne (10), maximum thickness was attained in the Pitanga well, where a depth of 460 meters was registered, giving a total depth of Itararé of about 500 meters, taking into account the overlying beds.

A thickness of approximately 1,000 meters of glacial beds may be assumed for certain areas of the basin, but it is necessary to bear in mind the unpredictable nature of the Basement complex. In the State of Paraná, the boring at S. José de Paranapanema reached the base of Itararé at 471 meters, penetrating the underlying Devonian shales down to a depth of 597 meters.

In Uruguay, the true glacial sediments are not particularly well developed. They have been classified by Uruguayan geologists as being intimately related to the Bonito group of the Tubarão series, forming the Bonito-Itararé series. The first evidence of glaciation in this region was found near Fraile Muerto. Du Toit (14) mentions the existence of various glaciation horizons, and beds of Bonito-Itararé are known in several places. In contact with post-glacial rocks, these beds exhibit considerable transgressions of Upper Permian and Triassic. The occurrence of Itararé in the well at Paso Ulestie (Uruguay) is of special interest. It occurs at a depth of 720 meters, below eruptives and Triassic sediments, apparently demonstrating a hiatus in the Passa Dois and Tubarão series. The tillites observed in the cores appear as a red clay-sandstone material with small boulders of granite and quartzite.

At present, there is no positive knowledge regarding the occurrence of glacial beds west and northwest of the Paraná Basin, that is, in the State of Matto Grosso and in Paraguay.

Glacial sediments contemporary with Itararé.—In the Argentine, glacial sediments contemporary with Itararé are known in the following regions north of Lat. 38° S.: Sierra de la Ventana (Province of Buenos Aires), conglomerate of Pillahuinco (15); Pre-Cordillera of San Juan and Mendoza; Sierras Pampeanas-Sierra de Umango and Pre-Cordillera do Norte (Province of Salta) (4); and the Tontal beds.

These beds rest transgressively on granites, Devonian rocks, or Upper Carboniferous, and appear in small outcrops along the Andes, extending north and south. With the exception of the Pillahuinco conglomerates, all these sediments are probably of marine glaciation. The outcrops at the Sierra de la Ventana are lithologically similar to the greenish gray tillites, with striated boulders, of Itararé, and lie discordantly on a bed of Devonian rocks.

In the Sierras Pampeanas region the Permian glacial sediments have been studied by Bodenbender, Hausen, Rassmuss, Keidel, and others. Together with the occurrences previously mentioned, in the Pre-Cordillera, these sediments are known as "Umango beds" of the La Rioja system of Lower Permian (3).

In the Falkland Islands, Halle (8) studied glacial sediments with tillites from the Lafonian series in the central part of the eastern island. The boulders described by Halle are of pre-existent rocks originating from a zone now submerged. The glacial beds are in discordant contact with the subjacent Devonian rocks.

In Southeast Bolivia and the northern part of the Argentine Pre-Cordillera, a well developed system of glacial sediments has been observed between Lat. 18° and 23° S.; they are the sediments comprising the Bermejo series of Heald and Mather, or the "Areniscas Inferiores" of Guido Bonarelli (4), of the North Argentine. Both the lower and middle parts of the Bermejo series—Oquita formation and Mandiyuti conglomerate—are typically glacial.

The Oquita formation (16) rests discordantly on the Devonian of the Totora series. It is of heterogeneous composition, with a coarse sandstone at the base, overlain by somewhat micaceous black shales and gray or reddish clay-sandstones, with small striated boulders of fluvio-glacial origin. The bed is 700 meters thick.

Overlying the Oquita is the compact Mandiyuti conglomerate, composed of vividly colored massive sandstone beds, intercalated with red shales. Topographically, they form extensive escarpments and cuestas in Southeast Bolivia. The polished and striated boulders are of granite, gneiss, quartzite, and basic rocks. They are also, apparently, fluvio-glacial or lacustrine deposits. The conglomerates are 500–1,000 meters thick, and are overlain by the non-glacial sediments of Macharetti, the total thickness of the beds being approximately 1,000–1,700 meters. They are considered as belonging to the Lower Permian, and may constitute two different glaciation horizons.

Several geologists admit a certain contemporaneity between the Dwyka of Africa, Talchir of India, and Itararé of Brazil, on the one hand, and the glaciation of Australia, Tasmania, and Western Argentina, on the other. However, confirmatory evidence is lacking and in the writer's opinion the relationship is doubtful, and can be sought only in the correlation of the probable centers of glaciation. These centers are apparently common for the sediments north of Lat. 38°, embracing the areas of South Africa and South America; other centers should be assumed for the areas south of this latitude, and for the other continents.

Structure and character of deposition.—The Itararé rests dis-

cordantly on granites and metamorphic rocks of the S. Roque and Assunguy series, except in the State of Paraná, where it covers shales and Devonian sandstones. In spite of detailed study of the numerous sections and outcrops, no signs of diastrophism or folding of these sediments were observed. The dips found in some parts of the basin are local in character and are due chiefly to the intrusion of igneous rocks abundantly distributed throughout the basin.

In Uruguay alone, in the Departamento de Cerro Largo, Falconer told the writer that he had found anticlinal folds of the Bonito-Itararé series resulting from the local action of basement masses in reciprocative compressive isostatic movement.

The observable stratification is generally cross-bedded. Nevertheless, in the majority of the outcrops, the sediments appear in thick unstratified beds of irregular deposition. The dark and black shales of the base are markedly horizontal, and in Santa Catharina they can be seen with vertical fissures and faults.

An examination of the well cores suggests generalized faults of considerable horizontal development. Drilling at Jaguariahyva (State of Paraná) indicates a possible fault in the contact between the Itararé and the underlying Devonian. In the areas between Jacarézinho and Jaguariahyva, several faults are also assumed between the Itararé and the Upper Permian and Triassic sediments, as shown by the wells at Wenceslau Braz, Barbosas, and elsewhere. The contact by faults is also known in Uruguay, between granites and the Bonito-Itararé series.

The varvites found in the wells are horizontally stratified. The occurrence of boulders in the clastic mass is sporadic, and they do not occur in specific stratigraphic horizons.

As has already been mentioned, in certain areas the São Bento series and Triassic sediments are in supposed transgression above the Itararé. It is well to mention the horst, of fair projection, which appears in the zone of Xarqueada (Pitanga), in the State of São Paulo, and which may also be characteristic of other areas.

In general, the glacial sediments of Brazil, like those of Karroo, did not suffer horizontal folding movements in the course of their deposition. This is contrary to what happened in certain parts of South Africa, the western part of Argentina and the Sierra de la Ventana, where strong inter-Permian tectonic movements were common (17).

As regards their characteristics and glacial facies, the Dwyka of South Africa and the Talchir of India are contemporary with Itararé. In the Hunter River district of New South Wales, however, the

lower horizons of glaciation are of Carboniferous age, as is proved by the *Rhacopteris* flora, and it is only in the Allandale conglomerate that Permian beds appear. This suggests that glaciation in this area began in pre-Gondwana time.

Character of glaciation.—The absence of striated surfaces on the pre-glacial rocks, the relative scarcity of striated, and the predominance of rolled boulders, the deposits of varvites and, finally, the existence of *Mollusca* in the series, lead us to conclude that the Itararé is not only of terrigenous fluvial glaciation, but is also in great part due to marine glaciation. It originated in the deposits from floating glaciers as well as in the sediments carried by the rivers and waters under the moving ice.

Based on certain striated surfaces observed in Uruguay and the Argentine, Du Toit (14) assumes that the glaciers descended from a continental mass situated in some part of the area now occupied by the Atlantic Ocean.

Halle (8) recorded the glacial sediments of the Falkland Islands as dipping south, with boulders of rocks which could only have come from a region outside those islands, thus showing the existence of glaciated areas at present unknown.

We must admit the existence of various large Permian glaciation centers at the beginning of the Gondwana era. Apparently, the glaciers moved from south to north, in the present territories of India and Australia, and from north to south, in Africa. The South American Continent (17) shows two glaciation centers, one in the northeast, comprising the glacial beds of Brazil, Uruguay, Argentina, and Bolivia, where there are signs of glacier movement toward the west, and the other in the south or southeast, connected with the Falkland Islands glaciation and the northward movement of the Antarctic glaciers.

It should be noted that the small folds described by Washburne (10) as evidence of glacier movement were also observed by the writer in various places in other formations, as in the beds of Rio do Rasto and Estrada Nova, and in Lages (Santa Catharina). Consequently such folds can not be directly related to glaciation: they would probably result from the local action of intrusive rocks.

Glaciation age (paleontologic observations).—As a whole, Itararé has yielded no fossils which will permit a precise chronogeological classification of the series to be made. Euzebio de Oliveira (12) found fossil *Mollusca* in 1908 in the Passinho well (State of Paraná), identifying them as *Lingula imbituvensis* (E.O.), *Orbiculoidea guaranensis* (E.O.), *Leda Woodworthi* (E.O.). Several remains of wings of insects

and plants were also found here. The same species of *Lingula* and *Chonetes* were subsequently found in the same shales west of Teixeira Soares. Euzebio de Oliveira (18) describes four new species of *Mollusca* found at Bella Vista, 6 kilometers south of Mafra (Santa Catharina); these are species of *Lingula imbituvensis*, *Orbiculoidea* sp., *Chonetes rionegrenses*, fish scales, sponges, and some undetermined fossils. These fossils were somewhat bituminous; they were examined by W. L. Bryant, who assigned them to the *Paleoniscidae* family.

The collection of marine *Mollusca*, found in Santa Catharina by Bastos and described by C. Reed as Permo-Carboniferous, contain the following species of particular interest (Washburne, 1930, page 36).

Aviculopecten (*Deltopecten*) *catharinea* Reed
Aviculopecten (*Deltopecten*) *relegatus* Reed
Aviculopecten (*Deltopecten*) *unicus* Reed
Aviculopecten (*Deltopecten*) *crassicostatus* Reed
Pseudamusium sp.
Stuchburria brasiliensis Reed
Edmodia sp.
Malomia cf. *cuneata* Dana
Solenopsis sp.
Schizodus occidentalis Reed
Schizodus (?) sp.
Agatherias cf. *micromphalus* Morr
Chonetes (or *Chonetella?*)

In the Argentine Pre-Cordillera, several species of brachiopods, gastropods, and bivalves of the *Productus-Spirifer* and *Pleurotomaria* orders were found in the marine glacial deposits of the Tontal beds. In the Appendix to Du Toit's work (14), Cowper Reed (19) attributes this fauna to the Carboniferous, relating it to the Carboniferous fauna of Russia and Asia. This thesis is based mainly on the work of Tchernischev, whose conclusions have been questioned by Schuchert. Schuchert's interpretation is the more acceptable to-day.

Du Toit unhesitatingly places the glaciation of Southern Brazil, together with that of Dwyka in Africa, in the Upper Carboniferous, and the same age must therefore be attributed to the marine and glacial sediments of Argentina. The latter, however, show a closer relationship with the analogous Permian sediments of Australia and Tasmania. Keidel (3), a leading authority on Argentine geology, is decidedly in favor of accepting the Permian as the age of glaciation of that country, while the recent studies of glaciation in the Sierras of Buenos Aires confirm the Permian age of the Pilhauinco sediments (15).

Detailed studies supported by additional paleontologic evidence are indispensable for a definitive chrono-geological classification. Considering the connection of the glaciation of the Paraná Basin with

that of Argentina and Uruguay, at present attributed to the Permian, the same age should be given to the Itararé. Nevertheless, we must consider the possibility that glaciation in the Southern Hemisphere may have begun in the Upper Carboniferous and continued into the Lower Permian. To justify this conception, it is sufficient to bear in mind the very large marino-continental masses affected by glaciation, and the existence of glaciation centers geographically widely separated. However, until more paleontologic proofs are available, we shall retain the conception of the Permian age for the Itararé glacial beds of Southern Brazil (20 and 21).

III. TUBARÃO SERIES

Stratigraphy and structure.—Resting conformably on the glacial tillites is a series of dark sedimentary sands and shales containing the *Glossopteris* and *Gangamopteris* flora. These beds were given the name of the Tubarão series by I. C. White (13). The series is composed of two groups: the lower, known as the Rio Bonito group, and the upper, the Palermo group.

The Bonito group is characterized by gray and yellow sands with several bands of dark-to-black shales, and contains the Coal measures of Southern Brazil.

The Palermo group consists principally of gray shales, light in color and with bands of sandstones; the upper part of the group passes gradually into the black bituminous shales of the Iraty. This series has been described by White (13) and others.

The Tubarão sediments are well developed from the State of São Paulo to Uruguay, but they do not everywhere appear in their typical stratigraphic sequence, the Bonito beds predominating in some areas and the Palermo beds in others.

There is no definite dividing line between the top of the Itararé and the Bonito group and it is the writer's opinion that the latter is also, in part, of glacial origin. We believe that the presence of boulders of older rocks should be used as the criterion for the division of the Tubarão series, *sensu stricto*, of immediate post-glacial sedimentation of fluvial character from the Itararé and lower Bonito that are composed of glacial sediments.

Coal beds have been located below the tillites of the Itararé in various places. Although some authors tend to attribute this apparent anomaly to "charriage" of the Itararé sediments over the Tubarão, tillites overlying the coal beds south of Campinas, in São Paulo, in the valley of the Rio do Peixe and at Wenceslau Braz in Paraná, as well as in the southern part of the State of Rio Grande do Sul, all

appear to lie *in situ*. Remains of the *Glossopteris* flora in the glacial sediments prove the existence of temperate climatic conditions during certain periods of the Permian glaciation. These phenomena can be explained as resulting from the periodic advance and retreat of the glaciers during the last stages of the glacial period. Such recessions, some of protracted duration, would permit the development of a flora which would be destroyed by the subsequent advance of the ice, and to them may be attributed the formation of the coal beds found between the glacial sediments. Similar advances and retreats of glaciers have been observed in regions both of recent and of contemporary glaciation.

FIG. 2.—State of São Paulo. Beds of Palermo group (Lower Permian) on Piracicaba-Tatuhy road.

The total thickness of the Tubarão series is variable. The only extensive outcrops are found in the State of Santa Catharina. The average thicknesses may be given as follows: São Paulo, 100 meters; Paraná, 90 meters; Santa Catharina, 250 meters; and Rio Grande do Sul, 150 meters. As a general average for all Southern Brazil, we may give the limits of 100–180 meters.

The coal beds are thin, varying from a few centimeters to 2 or 3 meters in some localities. They alternate with beds of sands and shales. Beds of limestone are commonly included, particularly in the Palermo group. Inclusions of silica "chert" are found throughout the entire series, being more common in the upper beds and gradually diminishing with depth. These "chert" occurrences are not syngenetic;

they are apparently due to infiltrations of silica-bearing solutions originating in the upper formation.

The Tubarão sediments are generally cross-bedded, and are of fluvial, and probably estuarine, deposition, as is shown by the composition and character of the coal-bearing beds and fossil plants.

In extensive areas, particularly in Rio Grande do Sul, and in Uruguay, the Tubarão occurs transgressively and directly on the granites and metamorphic rocks of the basement.

As in the Itararé, there are no indications of diastrophic orogenic movements in the Tubarão series. The structure is characterized by small faults and vertical dislocations of the component beds. These faults are easily observable in the coal mines of Barro Branco and in the numerous wells drilled in search of coal in Southern Brazil, as well as in the cores themselves.

Paleontologic aspect.—The typical fossils described by Zeiller (23), D. White (24), and others are found throughout the series. The lower beds are characterized by the "genera austral," for example, the following.

Gangamopteris cyclopteroides
Gangamopteris obovata (White)
Glossopteris browniana
Cordiates hislopi
Phylloteca griesbachi
Lepidopholios laricinius
Sigilaria bradrii
Lepidodendrum pedroanum
Pecopteris spp.

Disseminated through various beds are found: *Neuropteridium validum*, *Anularia australis*, and others; also there are sporadic occurrences of *Glossopteris indica*, *G. ampla*, and *G. occidentalis* in the upper beds. The occurrence of the latter leads one to believe that these "genera septentrional" of the *Glossopteris* flora emigrated from the Northern Hemisphere during the latter half of the Permian, and that they are not indigenous to the series, as Du Toit (14) infers when he considers the Tubarão and Itararé series as the chronological equivalent of the Upper Carboniferous.

Mention should also be made of the recent finding of fish remains in the Palermo beds of the northern part of Santa Catharina. These remains are apparently related to those found in Uruguay and described by Walther.

The Permian age of the Tubarão is also strongly supported by the paleobotanic classification of David White (24). Moreover, once the glacial period is referred to the Lower Permian, for reasons already given the Tubarão must correspond with the Upper Permian.

Formations contemporary with Tubarão.—The so-called "Estratos de Jejenes" of the Pampean series of Argentina, which follow the glacial sediments of the base of the "Estratos de Umango" are, apparently, contemporary with the Tubarão. Characteristic occurrences of these formations are described as sandstones and clayey shales, grayish-to-yellow in color, with impregnations and inclusions of calcareous material. At the base of these beds are found carbonaceous shales and thin beds of coal. The beds called "Piso I" by Bodenbender (25) vary from 30–300 meters in thickness. They are characterized by the inter-Permian diastrophism, which affected the Gondwana formations of Argentina, this characteristic being observable in the outcrops of the "Estratos de Jejenes."

Keidel cites the following as typical flora.

Neoggerathiopsis hislopi
Glossopteris communis
Gangamopteroides cyclopteroides
Euryphyllum whitianum
Neuropteridium validum

According to the logs given by Stappenbeck (26) relating to the wells drilled between Alhuampa and Gualeguay, in Eastern Argentina, the Tubarão must be included (if it exists) in the heavy beds of conglomerates cut at the bottom of the wells of Quimili, Alhuampa, Tostado, and San Cristobál. These logs demonstrate the considerable depression of the Permian Basin west of the Paraná River, and also show that this region was not affected by the inter-Permian diastrophism as was the case in Southern and Western Argentina.

According to Beder (27), carbonaceous shales are found at various places in Paraguay, at Santa Marta and Asunción, and these are apparently identical with the shales of the Bonito group.

In Uruguay south of the Jaguarão River, coal beds of the Bonito were found in several wells drilled. The maximum thickness of the Tubarão cut in the Melo well was 300 meters. The Palermo in Uruguay is very sandy and is hardly to be distinguished from the Bonito group in many localities.

In comparison with the Gondwana sediments of the other continents, the Upper Permian Tubarão corresponds with the Kárhabári and possibly the Barakar of Eastern India; with the Ecca coal-bearing beds of South Africa, and, finally, with the Greta coal beds of New South Wales.

The distribution of the *Glossopteris* and *Gangamopteris*, both in these territories and in the Antarctic Continent, is universal in character, although the various genera did not reach their maximum development and territorial distribution simultaneously.

IV. PASSA DOIS SERIES

Subdivision of series.—There is no evidence of unconformity between this series and the Tubarão, and we may consider the lower group—Iraty shales—as a continuation of the Palermo group.

To the present, there has been some confusion in the classification of the upper part of the series. Our own observations, together with the data published by Du Toit (14), Moraes Rego (11), and E. Oliveira (28) and based on Cowper Reed's classification of a large number of Triassic *Mollusca*, make it necessary to divide the series into three groups, of which the upper member, or "Rocinha lime" of White (13), must be separated from the two lower members and placed in the Triassic. There is probably unconformity between the Triassic and the underlying Permian. In spite of paleontologic evidence, no supporting stratigraphic evidence has yet been observed in the field.

In accordance with the aforementioned data, we divide the series as follows.

Permian {Iraty group
Lower Estrada Nova group

Unconformity

Triassic Upper Estrada Nova group

IRATY GROUP

Stratigraphy.—This group forms the base of the series and is well developed in the Paraná Basin. It can be observed from Rio Bonito to Rio Verde, in Matto Grosso and Goyaz (28), and as far south as Melo, in Uruguay. Its thickness diminishes from the center of the sedimentary belt of Paraná, on the north, and from the State of Santa Catharina, on the south. The most characteristic development of the Iraty is found in Paraná, in the southern part of São Paulo, and in Santa Catharina.

The Iraty has been described by I. C. White (13). In all its outcrops it is characterized by black bituminous shales, with thin beds of limestone. It is definitely classified by the remains of the reptile *Mesosaurus brasiliensis* (McGregor). In some outcrops, nodules of black silex are also found. This silex is impregnated with bituminous material and, when broken, emanates an odor of petroleum. The bituminous material of the Iraty shales in places amounts to approximately 100 liters per cubic meter, or 10 per cent by volume. In a great number of the wells, waters circulating below the limestone and shales are highly saline. Salt-water springs are found in some places in São Paulo and Paraná, while sulphurous water and gases have been found in some of the tests drilled in those states.

On weathering, the Iraty changes color to blue, light gray, or violet. In almost all the wells drilled in this group, the Iraty was found to be associated with magmatic intrusions generally distrib-

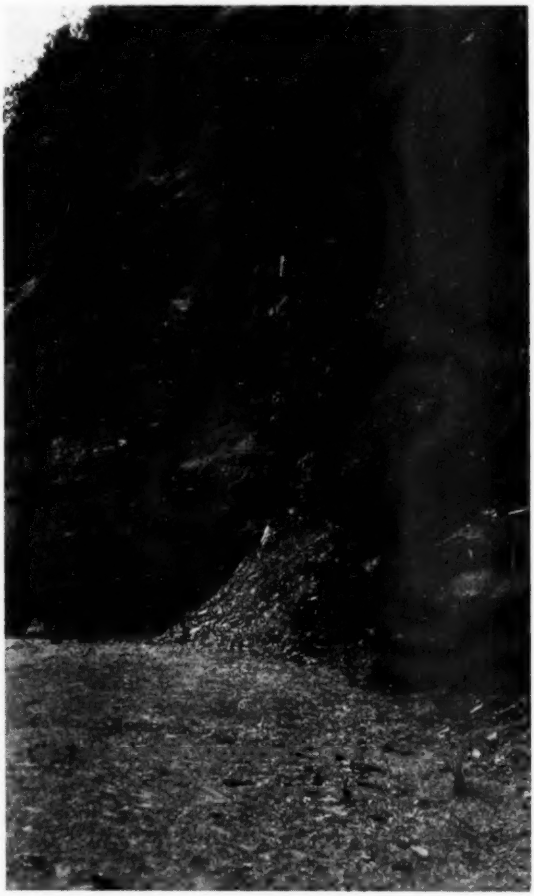


FIG. 3.—State of Santa Catharina. Dark beds of Lower Estrada Nova (Upper Permian) on Lages-Bom Retiro road.

uted at one level or more along the planes of schistosity. It is the writer's opinion that these intrusives are of Triassic age, and that they have risen along faults and structural fractures in the Iraty.

The shales offered little resistance to the intrusives, which were injected in thin sheets of considerable horizontal extension and varying thickness. Contact with the magma resulted in dehydration and distillation of the bituminous material, sometimes transforming it into albertite and grahamite.

The group is found in its normal stratigraphic position in all the wells which have been driven in Southern Brazil. In Western Uruguay (Paso Ulestie), and still farther west, at Entre Rios in Argentina, there is a hiatus of apparently the entire group.

The thickness of the Iraty ranges from 30 to 97 meters, the latter being found in the wells at Marechal Mallet, in Paraná. The Araquá well in São Paulo was drilled through 88 meters. The greatest average thickness, 70 meters, is found in the State of Paraná, the average for the whole group ranging from 30 to 60 meters.

The beds are well stratified and are generally horizontal where not affected by intrusive masses which in some places produce sharp dips of purely local extension. The Iraty forms an excellent key bed for structural studies. Data obtained from outcrops and well logs reveal a structure of faults and fractures over considerable areas of the whole basin.

Paleontologic considerations.—The fossils *Mesosaurus* (McGregor) and *Stereosternum* (Cope) are found in this horizon. They are found in abundance in the states of São Paulo, Paraná, Santa Catharina, and Rio Grande do Sul, as well as in Uruguay. They are not common north of São Paulo. Von Huene (29) claims that the *Stereosternum tumidum* is not a distinct genera from the *Mesosaurus brasiliensis*. He considers the two fossils as *Mesosaurus tumidum* and *Mesosaurus brasiliensis* and classifies them with the South African species which he studied under the single name of *Mesosaurus tenuidens*.

Reptiles presumably inhabited waters of high salinity, little depth, and lake-like character, in which the Iraty shales were deposited. These conditions, particularly the high salinity, explain the incomplete decomposition materials which gave rise to the genesis of the petroliferous and bituminous materials found in this group. In certain outcrops, such as at Lages, in Santa Catharina, the bitumen is found filling cavities formed in the shales by the impressions of the skeletons of reptiles.

Other fossils found in the Iraty include an unclassified crustacean, fish teeth and scales, petrified wood, et cetera. According to Walther (30) the fish scales found near Melo, in Uruguay, belong to the ganoid species. It is possible that these scales can be correlated with the fish remains recently found in the Palermo group of northern Santa Catharina.

The occurrence of *Mesosaurus* definitely places the age of the Iraty formations as Permian.

Geographic distribution.—The only known occurrence of *Mesosaurus* outside Brazil is in the "White band" of South Africa. According to Du Toit, there is a striking lithological similarity between these formations and the Iraty group.

Contrary to other areas of Gondwana rocks, the equivalent of the Iraty has yet to be found in Argentina. Nevertheless, contemporary rocks must exist in that country.

According to Beder (27), remains of *Mesosaurus* have been found in Paraguay, where the westernmost limit of the Iraty occurs. Fragments of remains of the same reptile found near Melo, in Uruguay, were shown to the author by Terra y Arocena.

LOWER ESTRADA NOVA

The sediments overlying the Iraty are also gray or dark shales with sandy intercalations, but lacking the bituminous material. Remains of *Mesosaurus* have not been found in these sediments. The thickness of this group is presumably between 50 and 70 meters. Owing to their lithologic similarity to the Triassic upper group, it is difficult to establish the dividing line between the two groups.

The group is characterized, paleontologically, by scales, bones, and coprolites of fish. Various specimens of plants and fossil wood have also been found in this group. David White (24) describes the wood as *Dadoxylon numularium* and *Lycopodiopsis derbyi.* The *Phyllopodos Leaia* of C. Reed (31) from Vallões, in Paraná, must belong to this group, which is undoubtedly of the Permian age.

The overlying group corresponds with the "Rocinha" of White, and is called the "Therezina beds" by Moraes Rego (11). We think the term Upper Estrada Nova more appropriate—"Upper" because there is a liability to confuse sediments of a different age and separated by an assumed hiatus when using the term "Estrada Nova." However, there is no inconvenience in leaving these sediments in the classic series created by I. C. White (13).

In Uruguay, the Lower Estrada Nova combines with the Iraty to form a distinct group called "Melo"—a classification well justified stratigraphically.

UPPER ESTRADA NOVA

Stratigraphy.—This group is composed of sandy clay shales, yellow, brown, violet, or variegated in color, with intercalations of sands of lighter color. The upper part is generally more clayey. The group is characterized by the presence of various beds of Triassic *Mollusca.*

The "Rocinha lime" is not restricted to Santa Catharina. Its equivalent may be observed at "Estancia Caleira," northwest of São

FIG. 4.—State of Santa Catharina. Sandstone dike in fault in Upper Estrada Nova (Triassic), on road between Lages and Bom Retiro.

Gabriel in Rio Grande do Sul; in siliceous limestones south of Canoinhas, in Santa Catharina; in the fossil beds of Serrinha and Therezinha, in Paraná; and in the siliceous beds of Ferraz and Camaquan in São

Paulo, described by Von Huene (31). These beds might correspond with the base of the Upper Estrada Nova, marking the transgression of the Triassic sea. However, the limestone is not uniformly distributed, being absent in many of the well logs. It is probable that this group does not exist in certain areas, the lower group only cropping out. The sediments of the two groups are well stratified and are essentially horizontal. The predominance of dark colors in the lower group is characteristic, the upper group showing brighter and reddish colors. This indicates a radical change in conditions at the time of deposition of the sediments. Apart from the limestone and various beds of sandstones, the group also contains concretions and beds of silex. Owing to the great variation in color and texture between one locality and another, in various states, it is difficult to establish a uniform lithologic criterion for the group.

Paleontologic considerations.—The essential argument for the subdivision of the Estrada Nova rests on paleontologic as well as lithologic evidence. The Upper Estrada Nova includes a great fauna of lamellibranchs unquestionably of Triassic age. Found originally by E. de Oliveira (12), and later by Du Toit (14), the *Mollusca* from Rio Claro, east of Marechal Mallet, in Paraná, were studied by Cowper Reed and classified as follows.

Zone I	*Pachycardia* aff. *rugosa* Hauer
	Anodontophora aff. *trapesoidalis* Mansuy
	Trigonodus aff. *rablensis* Gredler
	Radiolaria (undetermined)
Zone II	*Pachycardia neotrepica* sp. nov.
	Myophoria (*Myophoriopsis*) aff.
	Myophoria carinata Bittn.
	Myophoria aff. *lineata* Munst.
	Megalodus neotrepicus sp. nov. cf.
	Megalodus trigneter (Wulf)
	Gonodon (*Schafthantlia*) *paranaense* sp. nov.
	Modiola aff. *subcarinata* Bittn.

According to Reed there are no common species in zones I and II. The specimens from the two zones belong to the Upper Triassic. The *Mollusca* of zone I occur in the siliceous beds and chert, those of zone II being found above, in the beds of sandy limestone. The same beds extend in the direction of Iraty Station (São Paulo-Rio Grande Railway), and reappear at various points. At Serrinha, 7 kilometers northwest of Marechal Mallet, in the same place where Du Toit (14) found the aforementioned fossils, Karl Holdhaus (32) describes the following species.

Solenomorpha similis sp. nov. H.
Solenomorpha intermedia sp. nov. H.
Solenomorpha altissima sp. nov. H.
Solenomorpha reflexa sp. nov. H.

From the Agua Quente River he describes *Sanguinolites alongatus* sp. nov. H. and *S.* sp. Holdhaus considers them to be of Permian age, but Cowper Reed holds this classification to be doubtful. Subsequently, in the same locality, only Triassic fossils have been found, the species indicated by Holdhaus being unknown.

Beds of Triassic *Myophoriopsis* and *Pachycardia Mollusca* were also found by Huene in Ferraz and Camaquan, in São Paulo, and they are also particularly well developed at Therezina, in Paraná. Von Huene is also of the opinion that the Serrinha *Mollusca* are Triassic species of the *Myophoria* genera. The same species were observed by the writer at Lageado Piso, south of Canoinhas, and on the road to Lages, in Santa Catharina. The *Cuspidaria* species was found at Serrinha.

Apparently, the fossil beds can be related to the Rocinha limestone in Santa Catharina and the Caleria in Rio Grande do Sul. The limestone ranges from 1 meter to 3 meters thick. The *Mollusca, Terraia,* found at Cerro Hospital in Uruguay, appear to correspond with the Triassic species from Therezina and other typical localities in Brazil.

Geographic distribution.—The Estrada Nova is known to extend from the Rio Bonito and Jatahy, in the southern part of the State of Goyaz, to Aquidauana in Matto Grosso, and south as far as Uruguay. It is found in a belt approximately 10–20 kilometers wide along the older sediments already mentioned.

Owing to the difficulty of establishing the lower limit of the Upper Estrada Nova from the well logs, the thickness of the formation appears to be notably variable and completes the thinner Lower Estrada Nova.

The lithologic characteristics, and the fossils found, suggest that the Upper Estrada Nova was deposited in epi-continental seas, or during periods of ingression. This might explain the sporadic occurrence of the fossils, the irregular distribution, and the complete absence of the sediments of this group in certain areas.

Inasmuch as the Triassic referred to this group is the upper, corresponding with the Karnic or Lower Keuper of Germany (v. Huene) (31), and that the lower sediments are Permian, it is necessary to admit a hiatus of all the Lower and Middle Triassic.

In Paraguay, Beder refers to the same sediments at Villa Rica, where they appear with the outcrops of the Iraty.

In Uruguay, the Estrada Nova corresponds with this group, that is, with the Upper Estrada Nova, the lower groups of Permian age being considered as forming the Melo group.

In Argentina, Bodenbender (25) attempted to correlate the Estrada Nova with the Piso II. Keidel (3), however, considers the Passa Dois series as being contemporary with the Estratos de Catuna, and this may be correct as far as the Permian groups are concerned. The Upper Estrada Nova must, then, correspond with the Estratos Paganzo. As a matter of fact, a visible hiatus exists between the Estratos Umango (Permian) and the Paganzo (Triassic).

In Patagonia, *Myophoria neuquenesis* is found in the marine sediments of the Triassic ingression (33). The Vitiacua limestone of Southeastern Bolivia and the "Horizonte calcáreo dolomítico" of Northeastern Argentina are presumed to be contemporary with the limestones and silex beds of the Upper Estrada Nova.

In eastern India, the Passa Dois series corresponds with the lower part, "Raniganj," and the upper part, "Panchet," of the Damuda and Panchet series.

In the Karroo system the groups known as Beaufort beds correspond, in their lower part, with the Permian, and in their upper part with the Triassic, of the Passa Dois series.

SÃO BENTO SERIES

According to I. C. White (13), this series was originally composed of the sediments of the upper part of the Santa Catharina system, and the superimposed and intercalated effusive diabases. Subsequently, E. de Oliveira (12) gave the following names to the elements forming the São Bento series.

Rio do Rasto group
Botucatú sandstone
Eruptives of the Serra Geral

In view of later, more detailed investigations, the limits and positions of the sedimentary beds, hitherto interpreted in different ways by different authors, should take a position which appears to us the closest to their true cycle of deposition.

RIO DO RASTO AND BOTUCATÚ GROUPS

Stratigraphy.—The Rio do Rasto group proper, whose stratigraphic position has not yet been defined with exactitude, rests discordantly above the Upper Estrada Nova, forming a natural continuation of the latter. In its most characteristic areas it is composed of red or alternately red and greenish or variegated sandstones and clays.

Regional divergences.—The sediments of the Rio do Rasto appear in their most characteristic form in Rio Grande do Sul and Santa

Catharina, occurring in a somewhat less pronounced form in Paraná and São Paulo. In the latter states the group appears much more sandy, and resembles more closely the sandstone of Botucatú overlying the Rio do Rasto sediments.

In São Paulo the group is known as Piramboia (in accordance with the nomenclature adopted by the Geographical and Geological Commission of the State of São Paulo); it is incompletely developed and is even absent in certain places, such as Bôa Esperança in São Paulo. In Chiniquá (Municipality of São Pedro), however, there exists a fossiliferous horizon with remains of saurian fauna (31).

In Paraná, the group is of a much less sandy nature, mixing on the top with the sandstone of Botucatú and passing imperceptibly into the fossiliferous beds of the Upper Estrada Nova. Multi-colored clayey banks of this group are easily seen on the road to Guarapava, passing Prudentopolis.

In Lageado Liso (Canoinhas), in the northern part of Santa Catharina, there is visible contact of this group in discordance with the Upper Estrada Nova, the beds being sandy and yellowish in color. In the district around Lages, the Rio do Rasto is very sandy and light in color, showing a clear angular discordance with the Botucatú sandstone, although its aspect is very similar to the latter.

The group appears in its clayey and most characteristic surfaces on the road between Bom Jardim and Lauro Muller. No reptilian fossils were found in these beds, however.

In Rio Grande do Sul the group presents its most complete aspect, and is described in detail by v. Huene and Stahlecker (34). The beds are clays and light sandstones, friable, successively superimposed, and becoming more sandy at the base. In Santa Maria an intercalated bed of the same material, 53 meters thick, yielded a notable collection of Triassic reptiles of this group.

In its extension south, from Santa Ana to Uruguay, the Rio do Rasto is very sandy in texture, closely resembling the Botucatú sandstone. In Eastern Uruguay, in the Department of Cerro Largo, the sandstone outcrops bearing Triassic *Mollusca* should be related to the Upper Estrada Nova.

Red sandy clay beds similar to those of the Rio do Rasto are also known in Paraguay (Bella Vista), in Matto Grosso (Aquidauana), and in the southern part of Goyaz.

Structure.—The thickness of the group varies, the average being between 70 and 150 meters. It attains its greatest development in Rio Grande do Sul, where v. Huene (35) measured 380 meters, this figure undoubtedly including the Botucatú sandstone.

The characteristic structure is cross-bedded, without signs of folding apart from uplifts due to intrusive magmatic rocks.

The character of the stratification and the texture of the material presuppose a terrigenous eolian deposition, but the clayey beds of the base and the common occurrence of thin lenticular limestone beds suggest local aquatic conditions, probably fluvial, in Rio Grande do Sul.

Paleontologic observations.—The fossils associated with this group comprise reptiles and abundant remains of coniferous woods, chiefly of the *Dadoxylon* order. The lamellibranch *Mollusca*, usually connected with this group, should be attributed to the Upper Estrada Nova, which displays the marine facies of the Upper Triassic.

In Santa Maria da Boca do Monte, in Rio Grande do Sul, there are outcrops with numerous occurrences of saurian fossils such as *Scaphonix*, *Rhynchosaurus*, and *Erythosucus*. Some remains of the same reptiles were also found at Chiniquá, in São Paulo, and Leme (36) mentions the finding of remains similar to those of *Scaphonix* at Cambumbe, in the northern part of the Chapada of Matto Grosso.

According to v. Huene (35) and other writers, the Rio do Rasto appears definitely to belong to the Upper Triassic.

In Argentina, strata identical with this group are assumed, according to Rassmuss (37) in Sierra de Velasco and in the Pre-Cordillera; they are calcareous clays, although not characterized by fossil fauna.

In the Pre-Cordillera and in Sanagasta these sediments rest above the crystalline rocks, disclosing a considerable transgression in the deposition of the group. In Eastern Argentina, the wells from Alhuampa to San Cristobal show the presence of sediments of the series in varying depths. According to Stappenbeck (38), the lower level of the series at Alhuampa is at a depth of 1,630 meters.

In Northeastern Argentina the "Areniscas superiores," above the "Horizonte calcáreo-dolomitico," have the characteristic red, sandy clay beds of the Rio do Rasto.

The base of the Tacurú formation of Bolivia, composed of successive beds of shales and sandstones, has the characteristics of a deposition probably contemporary with the Rio do Rasto. Nevertheless, the former has not yet yielded fossils which would permit its definitive classification.

From the fossil fauna, the Rio do Rasto is apparently contemporaneous with the beds of Molteno sandstones in South Africa, with reptilian fossils corresponding with those described by v. Huene (29).

Botucatú sandstone.—In spite of the fact that the sandy facies of

the Rio do Rasto is with difficulty distinguished from the Botucatú sandstone, there apparently exists an angular discordance of local character on top of the group. Von Huene mentions it in several localities in Rio Grande do Sul, and the writer noticed such a discordance on top of the group in Lages, Santa Catharina. Washburne also refers to a discordance with a hiatus in São Paulo. Nevertheless, most of the outcrops of Botucatú sandstone lie concordantly above the Rio do Rasto. The bed consists of a sandstone varying in texture from fine to coarse, with strongly pronounced diagonal stratification. Outcrops occur as massive banks ranging in color from orange red to a slightly grayish white. The sandstone is invariably related to the

FIG. 5.—State of Santa Catharina. Counterforts of Botucatú sandstones (Rhaetic) on road from Lages to Bom Retiro.

eruptive escarpment of the Serra Geral and accompanies the latter for the whole of its extension, from Minas Geraes in the north, to Uruguay, where it is known as "Arenisca de Tacuarembó."

The Botucatú sandstone varies in thickness from 50 to 120 meters, forming steep walls along the escarpment. In many places, due to erosion, the sandstone joins the eruptives, forming extensive counterforts with evidence of considerably eroded Botucatú. This shows the considerable development of Botucatú before profound erosion took place.

With the exception of some remains of fossil worms found by Joviano Pacheco in São Paulo, footprints of small reptiles in São Paulo, and some undetermined remains of a reptile found at Passo Fundo, Rio Grande do Sul, by the same geologist, no other fossils of this horizon are known in Brazil.

Sediments contemporary with Botucatú.—On the top of the "Arenisca de Tacuarembó," near the city of that name, Walther (30) recently found some remains of a ganoid fish which he classified as *Seminotus*. Without doubt, the sandstone of Botucatú has all the characteristics of eolian desert deposition. However, the remains of the Tacuarembó fish, if belonging to the Botucatú sandstone, imply the existence of an aquatic or lacustrine facies in the extreme southern part of the Paraná Basin. The basaltic rocks observable in this region support this inference: these rocks are extremely amygdaloidal and some of them suggest that they were ejected while submerged.

No sediments contemporaneous with those of Botucatú have been observed in Argentina.

It is probable that the discordance between the Pampeanas series and the Liassic sediments with plant remains, in Patagonia and in the Cordillera, corresponds with the deposition period of the Botucatú of Brazil.

Transgressions of eruptives with a hiatus of the lower sedimentary and Triassic parts of the series are also observable in Uruguay.

The Cave sandstones of the Stromberg series in South Africa, and the Mahadeva formation of India, are apparently contemporaneous with Botucatú.

According to the stratigraphic evidence, the Botucatú is of the Rhaetic or Upper Permian age.

Capping the Botucatú are enormous masses of effusive rocks covering the greater part of the Paraná Basin.

Caiuá sandstones.—In the western part of the State of São Paulo there exists a sedimentary bed related in age to the basaltic trap on which it rests: this is the Caiuá formation, thus called by the State of São Paulo Geographical and Geological Commission, and described in detail by Washburne (10). It is friable sandstone, bright red in color, everywhere much decomposed in outcrops, free of interpolations of clay or gravel of any kind, thus confirming its eolian origin. The stratification shows pronounced deposition in dunes.

The Caiuá has certain affinities with the Botucatú sandstone, although it is mixed with the material resulting from the deep erosion of the traps. In certain places, its thickness reaches 50 meters. No fossil remains were found in this bed; nevertheless, its affinity with the Botucatú and its stratigraphic position above the basaltic trap suggest that its age is Jurassic. E. de Oliveira (28) places the Caiuá sandstone of the western part of São Paulo and southern part of Matto Grosso, together with the eruptives of the Serra Geral, on top of the Upper Triassic (Rhaetic).

No deposits of Caiuá sandstones are known in the remaining states of Southern Brazil.

VI. TRAPS OF SERRA GERAL

Geographic and stratigraphic distribution.—The basaltic traps of the Paraná Basin constitute a physiographic and morpho-geologic factor of the greatest significance in the geology of Southern Brazil. The traps cover Northwestern and Western Uruguay, a large part of the Territory of Missiones and Northeastern Corrientes in Argentina, and the whole of Western Paraguay.

The geographic limits of the traps are: on the north, Lat. 18° S., embracing the central areas of the State of Goyaz and Minas Geraes; on the south, Lat. 33° S., embracing Uruguay as far as the southern boundary of the Rio Negro valley; on the west, Long. 59° W., in Argentina, and on the east, Long. 49°30′, forming the Serra Geral of Brazil, with maximum extension reaching the Atlantic coast at Torres, in the State of Rio Grande do Sul.

The total visible surface area of the trap, together with its extensions under the post-Gondwana sediments as observed in the wells in Uruguay and Entre Rios, in Argentina, is approximately 1,200,000 square kilometers. The area covered by the trap in Brazil is 900,000 square kilometers, and embraces the states of Goyaz, Minas Geraes, Matto Grosso, and the larger part of the states of São Paulo, Paraná, Santa Catharina, and Rio Grande do Sul. The whole of this huge area extends northeast and southwest, and has a maximum longitudinal axis of 1,700 kilometers, the east-west transverse axis measuring approximately 1,000 kilometers, at Lat. 28° S. This area forms the most extensive effusion of basaltic rocks ever observed on earth.

Similar in characteristics, although smaller in area, are the Triassic and Jurassic traps of the Karroo, the Cretaceous traps of the Deccan, the 500,000 square kilometers of Tertiary basalts in Oregon, Nevada, and Idaho, the extensive effusions, 1,000 meters in thickness, of the lavas of Greenland, Spitzbergen, the Hebrides, and Scotland, and the lava traps of Patagonia and the Antarctic Continent.

The absence of volcanic cones, the surprisingly uniform composition of the diabases throughout considerable areas, and the structural uniformity of the various traps show that the effusions were quiet and successive, but with ejections of extremely fluid lava.

The eastern margin of the trap in Brazil forms a continuous basaltic escarpment extending from Uruguay to the State of Minas Geraes. In spite of its magnitude, however, little importance has

hitherto been attached to this major geographic feature of Southern Brazil.

The morphologic significance of the Serra Geral—name given by White (13) to the margin of the trap in Santa Catharina—is comparable with that of the Serra do Mar, particularly considering its length of nearly 1,500 kilometers and its average elevation of 800 meters with peaks reaching 2,000 meters (Campo dos Frades, Santa Catharina). The western, northern, and southern limits of the trap are not so clearly defined, due to their being overlain by post-Gondwana sediments. Nevertheless, the wells at Pazo Ulestie (Uruguay) and those from Gualeguai to Alhuampa (Argentina), together with the outcrops of Triassic basalts in Paraguay and the State of Matto Grosso, make it possible to establish its limits with fair accuracy (39).

The surface of the trap is denuded and free from post-Gondwana sediments throughout large areas, affording evidence of considerable erosion and topographic lowering of the area from the Mesozoic to Recent time.

There is insufficient evidence to make possible an exact chronologic classification of the trap. In spite of this, it is evidently limited by the Upper Triassic below and the Liassic above. In all probability, the Rhaetic age marked the period of maximum development of the traps, while the process of effusion may have begun in the Triassic and continued into the Liassic.

Petrographic observations.—Petrographically, the traps were studied in detail in the excellent work of Djalma Gu marães (40), and by Hausen (41) and K. Walther (42) as regards the erupt ves of Argentina and Uruguay.

> The microscopic physiography of the basalts of the south part of the country, forming its chief magmatic province, varies with the conditions under which the rocks were consolidated. The mineralogical composition is practically uniform, with local variations characterized by the concentration of magnetite-ilmenite in proportions which may exceed 20 per cent. All the successive phases may be found among the representative types of the Triassic magma on the south, from holo-crystallines of ophitic and interstitial, to micro-crystallines of microlitic texture. (Djalma Guimarães, *op. cit.*, page 9.)

The nature of the eruptives is singularly uniform and s'mple. They are almost all basalts free from olivine-basaltites (plagioclase with phenocrystals of augite and magnetite), diabases, and melaphyres. The melaphitic types are particularly plentiful in the peripheric areas of the trap, with poorly developed amygdaloids in the com-

pact basaltic mass of the Serra Geral (Bom Jardim, Santa Catharina) escarpment, and excessively vesicular and amygdaloidal types in Uruguay and Argentina.

The predominating color is gray, but may vary from black to slightly violet, reddish, and slightly green. Coloration depends partly on certain chloritic and hematitic impregnations, and partly, as regards the surface, on climatic conditions and atmospheric precipitations. The deep decomposition of the basalts is specially noteworthy in the State of São Paulo (terra rôxa) and in the Missiones Territory of Argentina.

With the exception of tuffites, volcanic breccia, and cineratic sediments existing in Minas Geraes (Triangulo Mineiro) (40), very few remains of explosive eruptions have been found in the huge area of the trap.

Thickness of the trap.—This varies considerably at different points in the basin, this being in part due to the considerable erosion already mentioned. The thickest basaltic body penetrated by drilling in Brazil was 147 meters (Bôa Esperança, São Paulo), in a laccolith not completely measured.

Morpho-geological genesis.—The Serra Geral escarpment belongs to the Cenozoic age. It originated from the differential erosion of the Botucatú sedimentary beds. These beds were contemporary with the escarpment, and probably formed a ridge of desertic accumulations flanking the western border of the old mass of the Archean shield. The successive flows of lava were retarded in their advance toward the east by this barrier of sediments of the São Bento series.

The intense Cenozoic erosion, and the isostatic raising of the coast at this period, resulted in the disappearance of the large sedimentary beds of the São Bento series that formerly covered the area between the present Serra do Mar and Serra Geral. The erosion also cut deeply into the subjacent Permian sediments. Figure 6 shows the process schematically, it being particularly suggestive in certain places in the states of Santa Catharina and Paraná.

Most of the western border of the trap does not constitute a physiographic feature of the topography of the region, since it dips below the post-Gondwana sediments.

There is an erosion escarpment on the margin of the trap, in Eastern Paraguay, west of this escarpment and south of Assunçión (27), where rocks of the Archean complex appear. As in Brazil, the profound erosion has denuded the Permian sediments and uncovered the margin of the trap.

Contrary to what occurred in the east, where there were the con-

siderable sedimentary accumulations already mentioned, the lavas met with no obstacles in their expansion toward the southern margin of the trap, and directly covered the rocks of the complex (State of Goyaz) or, transgressively, the Permian sediments (Uruguay). In these

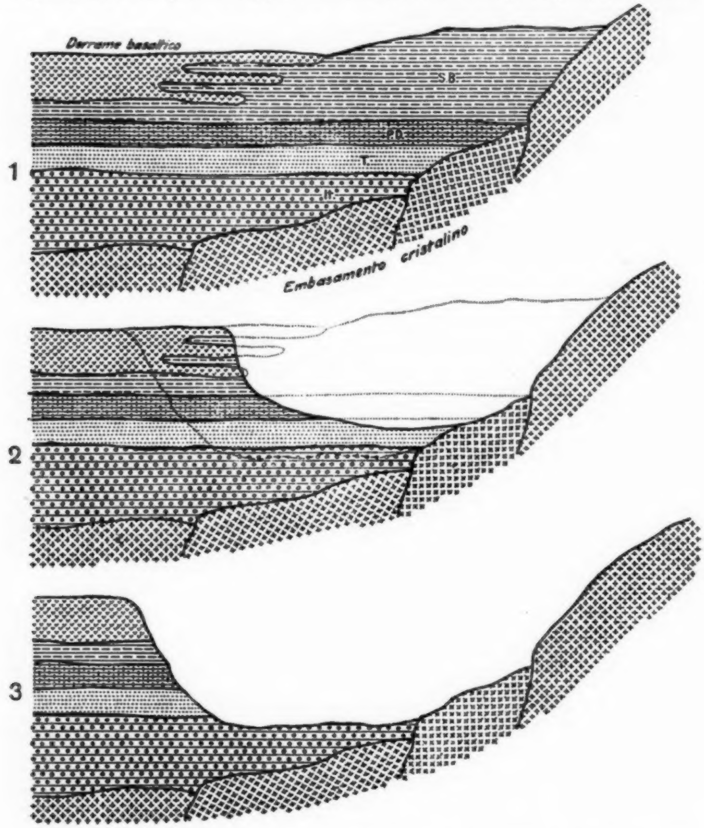


FIG. 6.—Sketch of successive phases of erosion of sedimentary belt along eastern flank of Serra do Mar. Phase 3 shows present aspect of escarpment of Serra Geral (left) and Serra do Mar (right).

regions there is no pronounced escarpment, and the trap cover is thin.

In the southwestern part of Santa Catharina and northwest of Rio Grande do Sul, the continental depression favored the westerly advance of the lava, which extends into the sea at Torres. Here also, the trap escarpment closely follows the outline of the basement masses as

well as the borders of the depression on the north and south, where they gradually thin out.

Types of contact.—The contacts between the effusives and the Botucatú sandstones may be classified in the following three types: (a) in contact with the counterforts of the Botucatú sandstones, (b) in *en dents de scie* form of contact, and (c) in the form of successive

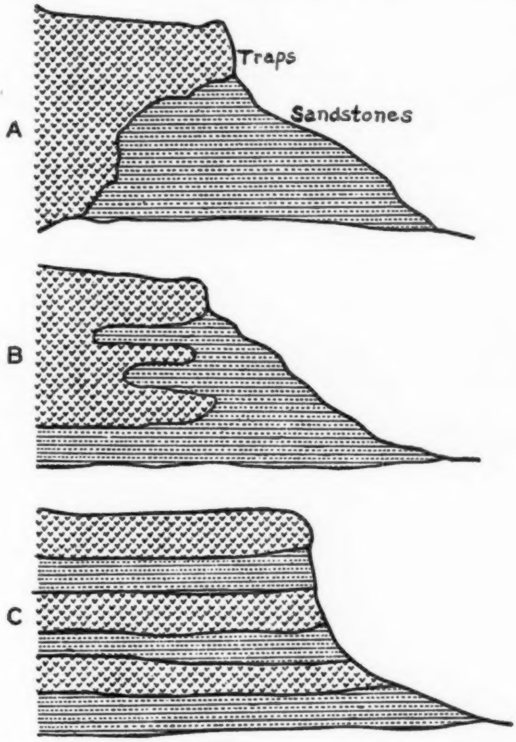


FIG. 7.—Forms of contact of Serra Geral traps with Botucatú sandstones.

traps, with interposition of sedimentary beds of Botucatú of irregular thickness. Figure 7 shows these types of contact.

The metamorphism of the sandstones of the São Bento series in contact with the effusives may be seen in many places, and appears in the form of fusion of the sandstones, which are transformed into a highly compact quartzite of conchoidal fracture. This metamorphic action was local and had very little effect on the deeper parts of the beds.

VII. TECTONICS OF PARANÁ BASIN

Structure of the trap.—Considered as a whole, the Paraná Basin is undoubtedly a continental depression with the character of a "geosynclinorium." The writer's observations in this connection amply confirm the opinion of Baker (39):

> Structurally, all this region is a single vast downfold (geosyncline)

and Walther (42):

> . . . es seguro por mas que faltan investigaciones detalladas que en muchos pontos la disposicion tectonica de los estratos que yacen en posicion casi horisontal, obedece a la de bloques de falla (fault blocks).

The synclinal axis which crosses the basin northeast and southwest south of Lat. 27°, clearly dips southwest. The western depression (west of the Serra Geral escarpment) inclines markedly northwest in the area north of Lat. 24°, west between Lats. 24° and 28°, and southwest between Lats. 28° and 32° S.

The general horizontality of the successive beds of the trap, observable in the greater part of the basin, does not permit the establishment of dips, even of local character. However, when the factors of their profound erosion are borne in mind, the varying elevations of the effusive mass above seal-level prove that it is composed of fractured blocks, faulted and extended *en échelon* from west to east. By establishing an altimetric relationship between the various trap areas, one deduces an average of 2 meters per 1,000 for the westward dip.

The Serra Geral reaches a height of 1,600 meters above sea-level around Bom Jardim (Santa Catharina); the rocks of the trap are found at 300 meters below sea-level in the drilling at Pazo Ulestie (Uruguay), and at an elevation of 120 meters at the mouth of the Iguassú, in Paraná.

In the southern part of Matto Grosso, and in São Paulo, between Lats. 18° and 24° S., the southern area of the basin reveals structural characteristics of a graben whose axis clearly follows the course of Paraná River. The eastern margin forms a monocline with the ascending blocks reposing on the Serra do Mar.

The folding of the Andean Cordillera did not affect the Gondwana of Southern Brazil, and the absence of other folding factors or orogenic diastrophism in the post-Gondwana of this part of the continent causes the Gondwana to show a tectonic character somewhat different from the greater part of the other major effusions, such as those of the Karroo systems. In spite of the evident correspondence between the traps of Karroo and those of the Paraná Basin, which assumably are

contemporary, the latter suffered much less intense fracturation and diastrophic disturbance than the former.

Due to the acute erosion of the trap surface, and to the relatively slight vertical projection of the faults, the latter are in general not conspicuously exposed. These faults are, however, well in evidence in the river beds. The rivers, with numerous waterfalls, cut deeply into the trap and form the extensive hydrographic system of the basin.

From the stair-like character of their banks in certain places, it seems probable that the valleys of the larger rivers, such as the Tieté, Paranapanema, Ivahy, Iguassú, and Uruguay, occupy the zones of faulting of separate blocks. These masses, *en échelon*, descended gradually from north to south, in the direction of the longitudinal axis of the basin. It is probable that the tectonic factors which caused the

FIG. 8.—State of São Paulo. Escalonated escarpment of Itaquery Serra.

faulting of this considerable area operated in post-Triassic time, and that they were connected with the isostatic depression of the basin, possibly at the same time that the synclinal depression of the Chaco Territory occurred. It is also possible that the fractures occurred at the end of the Triassic, causing the effusion of magma, and that they persisted after the latter had cooled and formed the solid mass of the trap. The last hypothesis could be related to the *mise en place* readjustment of the separated epirogenic masses which, up to that time, formed the probably connected continental mass of Gondwana.

Structure of sedimentary basin.—The narrow strip of sedimentary deposits between the complex of the Serra do Mar on the east and the escarpment of the Serra Geral on the west is evidently the outcropping margin of the large sedimentary plain stretching toward the west in Southern Brazil. Nearly the whole of this plain is covered with basalts.

Structurally, this strip corresponds with the tectonic facies of the trap, showing a tendency to depression toward the western quarter in São Paulo, Paraná, and Santa Catharina, and toward the southern or southwestern quarter in the southern part of Santa Catharina and in Rio Grande do Sul. In São Paulo, Paraná, and Santa Catharina the average elevation of the sedimentary area is 700 meters, and in Rio Grande do Sul, Uruguay, Matto Grosso, and Paraguay the average elevation of the outcrop is 150 meters.

The sedimentary beds of the Paraná Basin have not suffered orogenic movements or pronounced diastrophism since their forma-

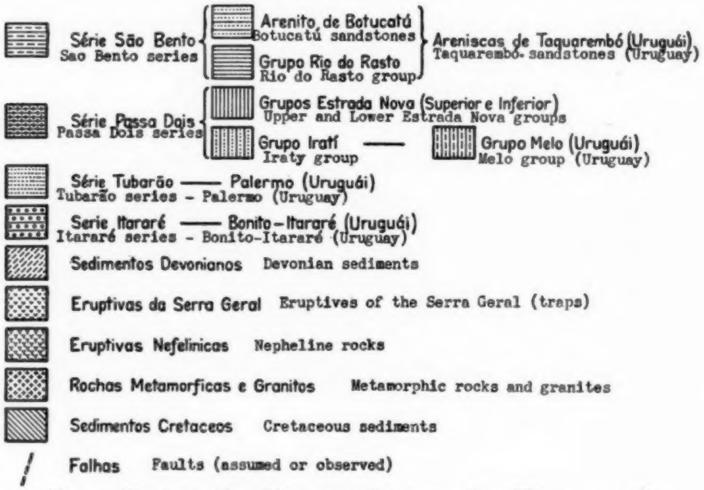


FIG. 9.—Key to stratigraphic sequence in cross sections (Figs. 10, 11, 12).

tion in the Permian or Triassic, although the type of fracturing of the trap and throughout the basin also affected the bordering sedimentary areas.

The structural and characteristic factors greatly affected the sedimentary belt. In the first place are the magmatic intrusions in the form of dikes, with extensive ramification, such as sills, necks, and even intrusive batholiths. In the second place are the fractures and faults, generally of low vertical displacement and covering a large area: these are chiefly related to the magmatic intrusions, for which they offered a means of penetration. Superficially, these faults do not form well marked contours, this being due partly to the same intense peneplanation as was previously mentioned in connection with the

trap surfaces, and partly to the homogeneity of the clastic masses composing the sedimentary rocks.

In general, the faults show low vertical projection, although drilling proves the subsurface presence of large faults with 200 meters or more displacement, such as those verified in the small area of drilling at São Pedro, in the State of São Paulo. The presence of faults has been proved in all those areas where there are a number of wells close to one another.

The fractures are apparently well developed along the line of the contacts from north to south, this conclusion being supported by the structure of the faults observable in the Serra do Mar, in São Paulo. The development of the system of east-west faults is much greater, and covers the whole basin. The numerous logs of wells throughout the sedimentary area supply considerable material for determining the structure of the area.

The Iraty shales appear as a key bed of unmistakable characteristics in the stratigraphic column. A continuous correlative study of this horizon fully confirms the tectonic character of the sedimentary belt.

The diastrophism already mentioned affected the trap and the subjacent sedimentary rocks simultaneously, as well as the base of metamorphic and crystalline rocks of the complex.

The intrusives, which rest in considerable areas on top of the sedimentary series, apparently belong to various eruptive cycles since, apart from the preponderant basalts, several intrusions of acid and nepheline rocks are known in the southern states, as for example in Lages, Santa Catharina.

The intrusives greatly affect the form of the sedimentary rocks, creating structures of local character and, in some areas, of accentuated relief, and they may form conic or asymmetric domes, most of which extend in the direction of the Serra Geral.

The orography of the belt has the character of a peneplain with intrusive protuberances and evidence of erosion, generally along the escarpment. Considerable areas of the intrusives have been bared by the acute erosion, thus creating extremely fertile areas of decomposed basalts (terra rôxa).

Owing to the characteristic cross-bedding of the sediments, it is not possible to consider the apparent stratification as of true tectonic value. The decisive factor in the structural study of a region with the peculiar conditions of the Paraná Basin should be sought principally in the correlation of the logs of the wells, as we have studied them.

Summary.—Tectonically, and in a general way, the Paraná Basin

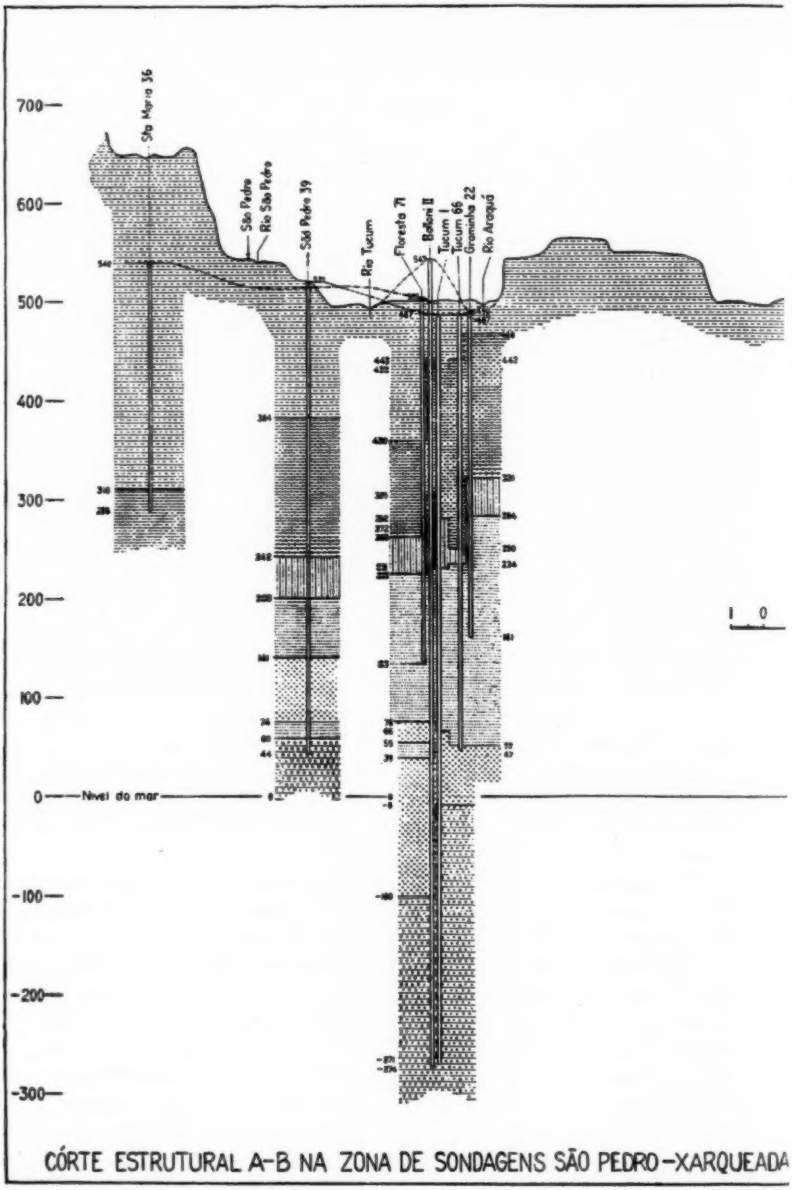
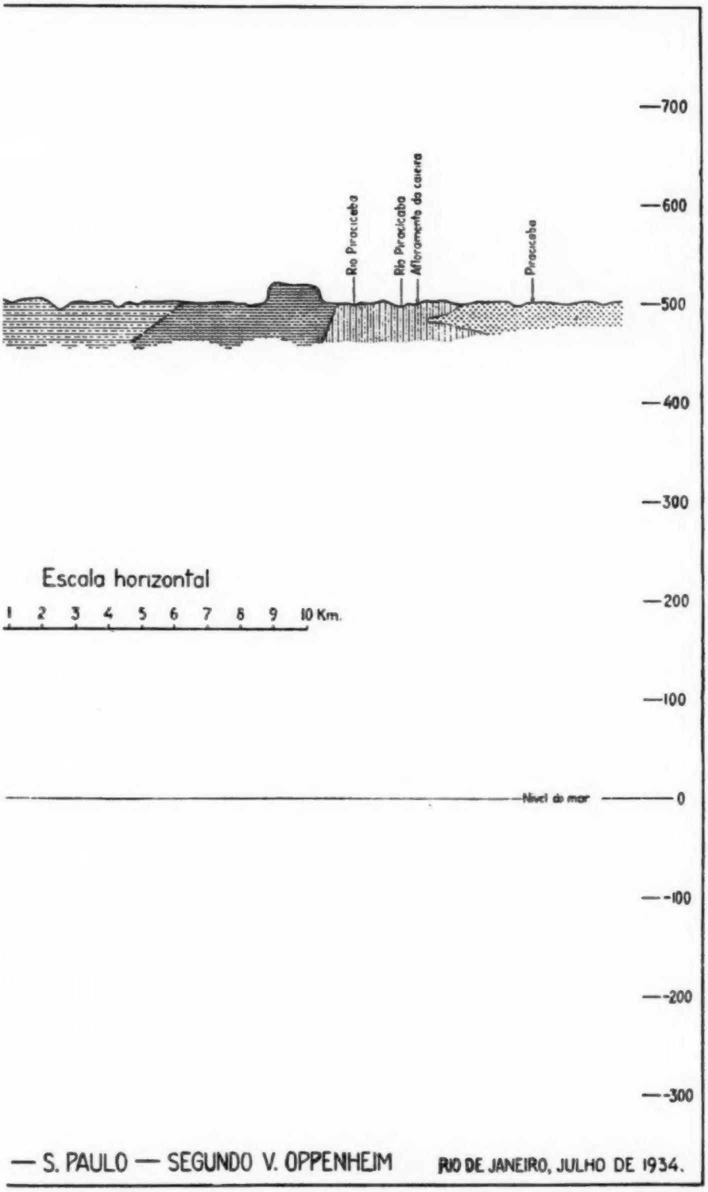


FIG. 10.—Section *AB* of São Pedro-Xarqueada area, State of São Paulo. Location



shown in Figure 13. Vertical scale in meters above and below sea-level.

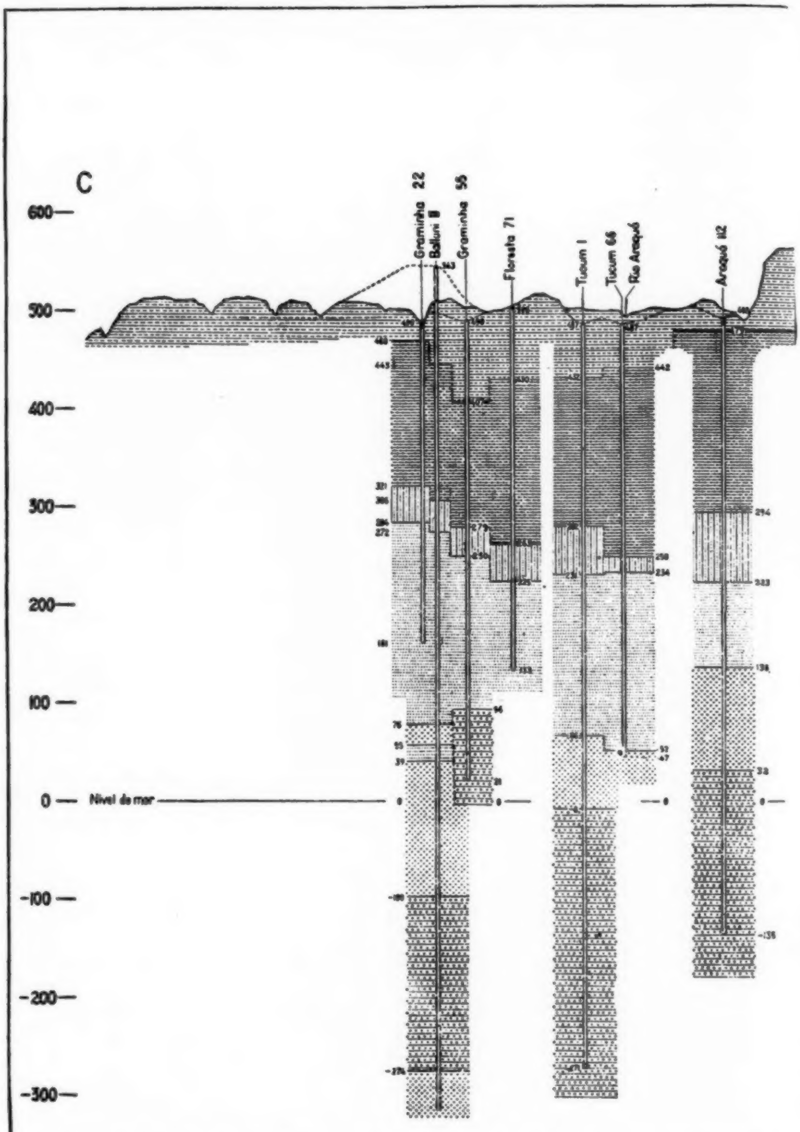
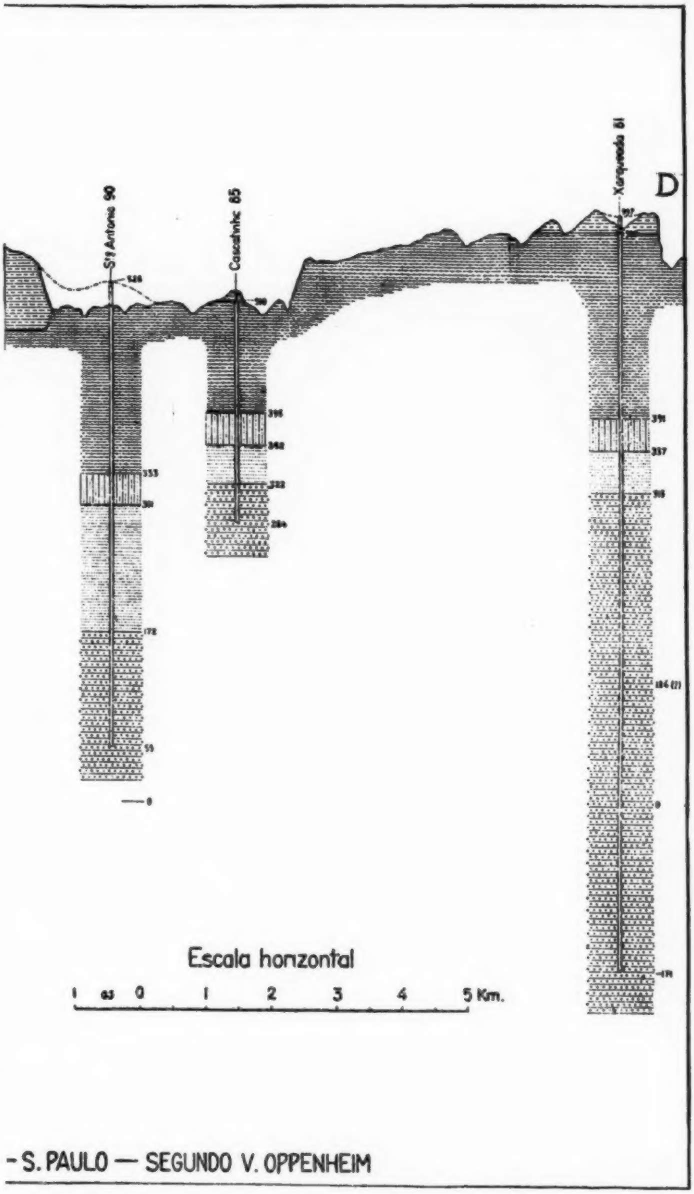
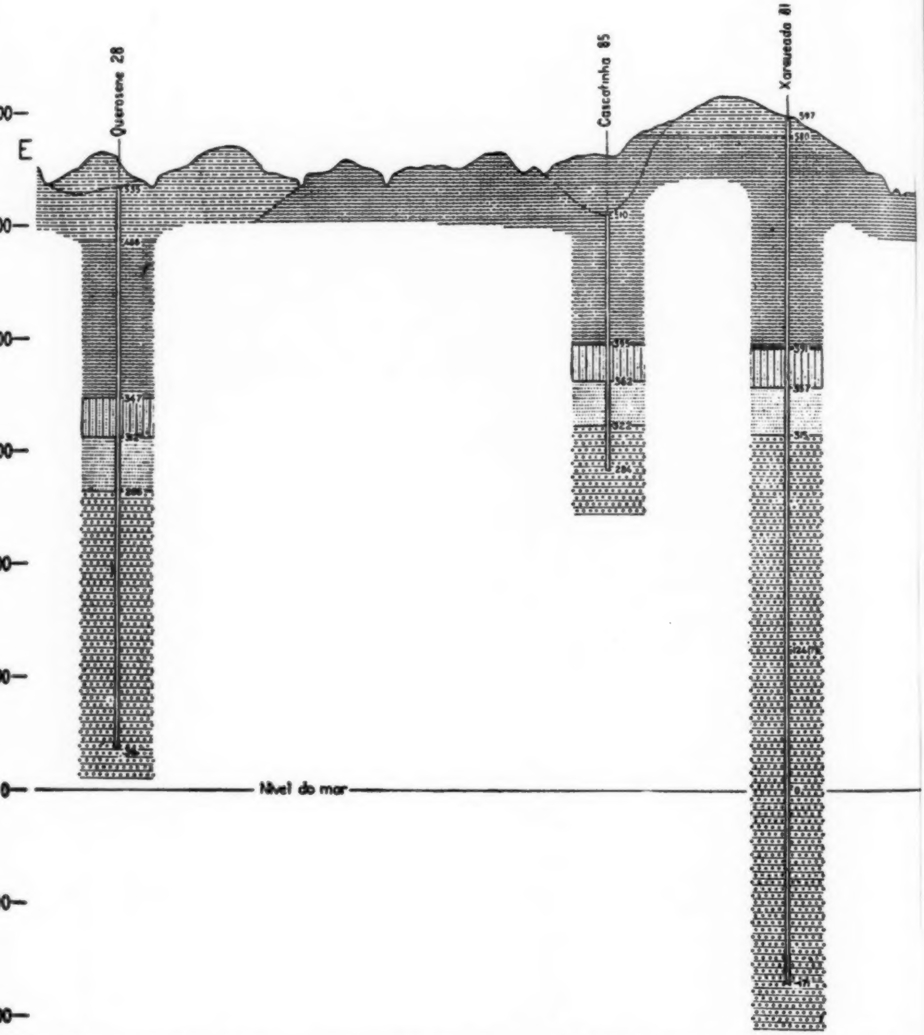


Fig. 11.—Section *CD* of São Pedro-Xarqueada area, State of São Paulo. Location

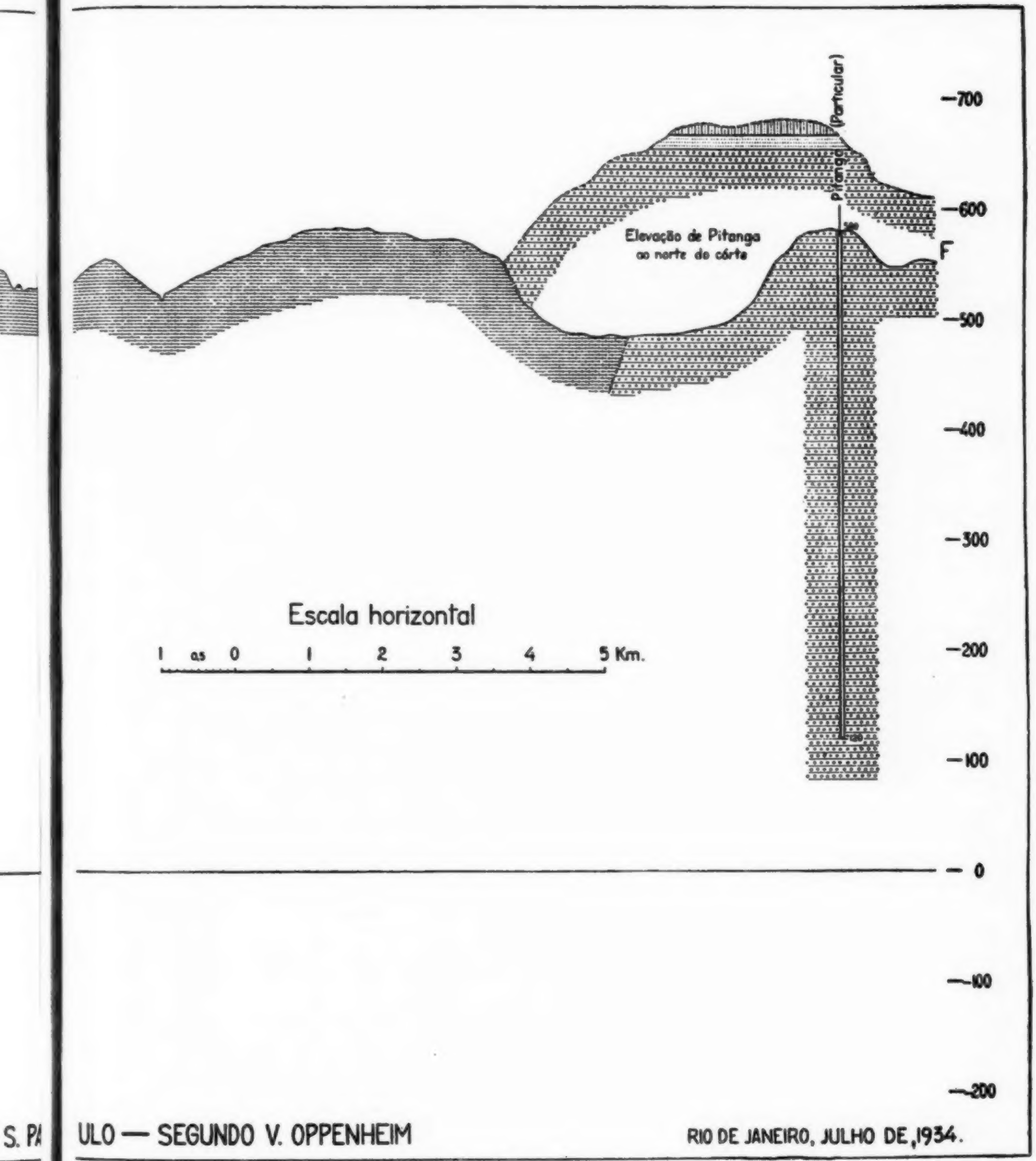


shown in Figure 13. Vertical scale in meters above and below sea-level.



CÓRTE ESTRUTURAL E-F NA ZONA DE SONDAGENS SÃO PEDRO-XARQUEADA — S. PA

FIG. 12.—Section *EF* of São Pedro-Xarqueada area, State of São Paulo. Location



cation

shown in Figure 13. Vertical scale in meters above and below-sea-level.

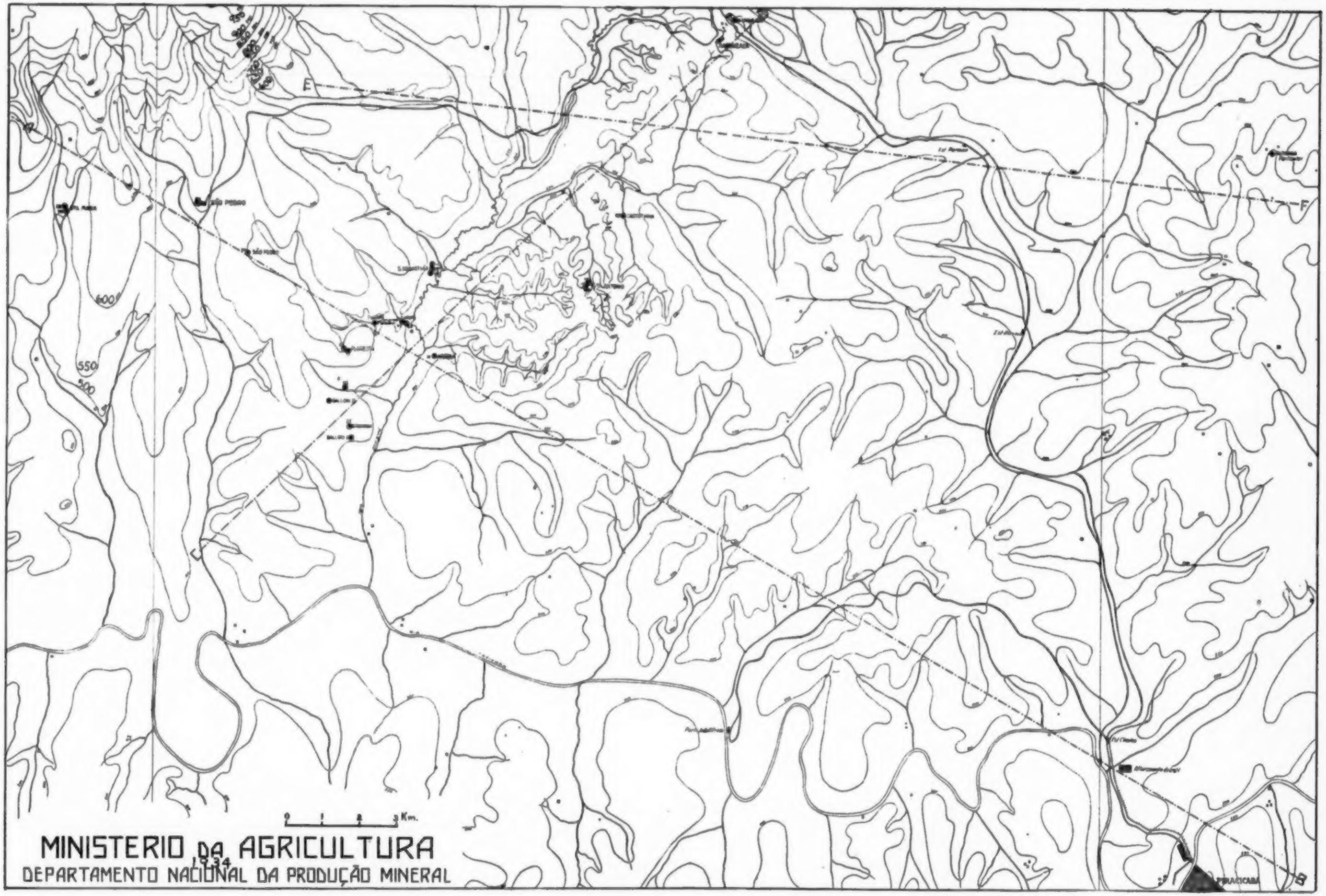


FIG. 13.—Map showing location of wells drilled for oil at São Pedro, Xarqueada, and Piracicaba in State of São Paulo. Locality of this map shown on regional map (Fig. 14). This map shows location of sections *AB* (Fig. 10), *CD* (Fig. 11), *EF* (Fig. 12). Topographic contour interval, 50 meters (sea-level datum). *Serviço de Fomento da Producção Mineral* (Brazil, 1934).

is a geo-synclinorium of graben character between Lats. 18° and 24° S., and a monocline on the south, between Lats. 24° and 33°. The internal structure comprises faults and fractures *en échelon* from east to west, strongly developed in successive steps of slight displacement. The same characteristics are shown in the north-south belt.

The whole of the eastern margin of the basin borders the crystalline complex, and the western margin forms the continuation of the Chaco depression and Eastern Argentina. Thus, the stratigraphic

TABLE IV

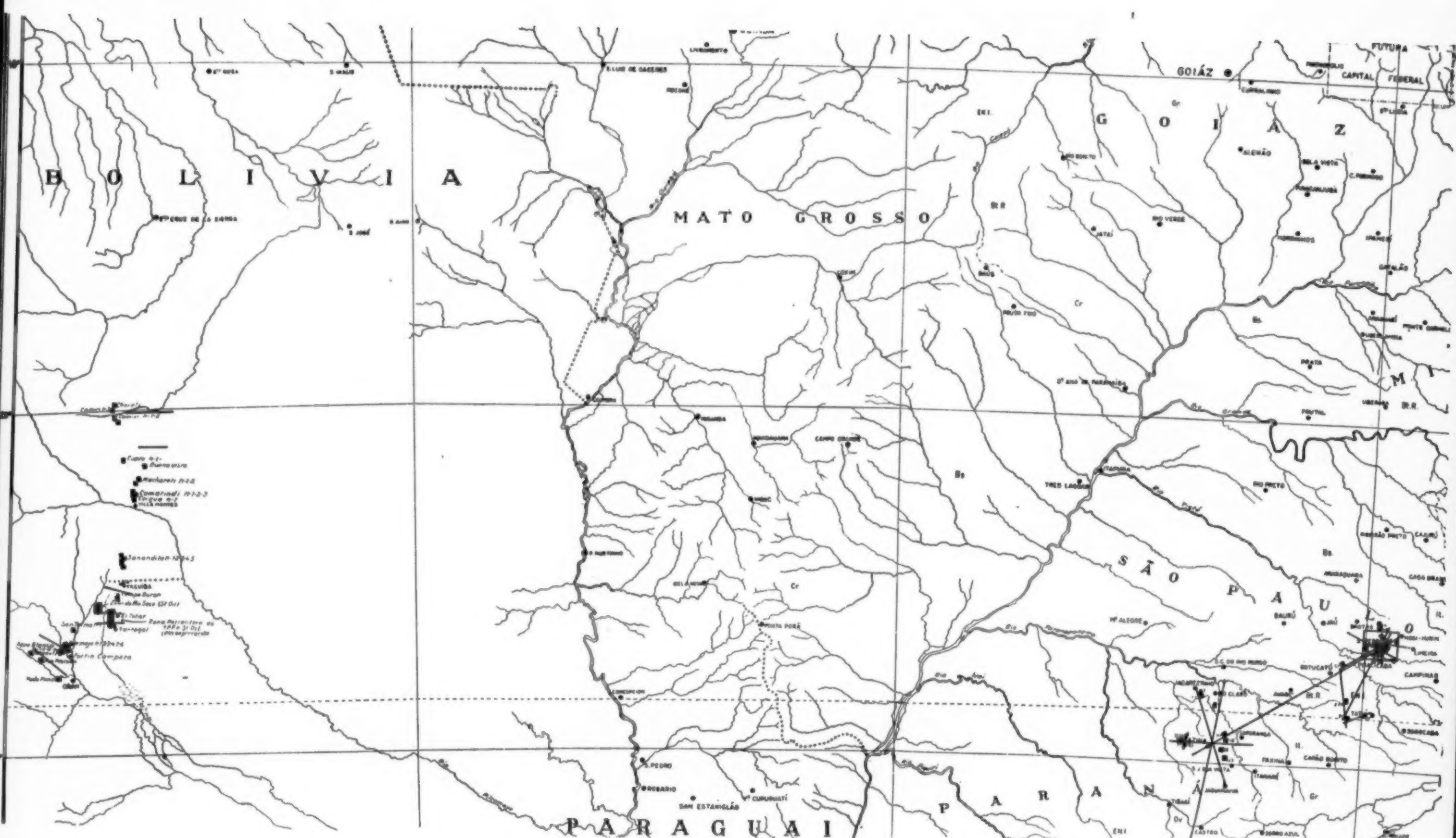
SUMMARY OF LOGS OF ALL PRINCIPAL WELLS DRILLED IN SOUTHERN BRAZIL

Name of Well	*No.*	*Total Depth*	*Elevations* in Meters Above Sea-Level of Bases of*						*Diabases (Main Intrusions)*
			D.F.	*S.B.*	*E.N.*	*Iraty*	*Tub.*	*Itar.*	
				STATE OF SÃO PAULO					
Graminha	22	329	490	468	321	284	161§		
Kerosene	28	499	535	486	347	312	265	229§	
Sts. Maria	32	212	540	328§					
Itirapina	34	325	731	503					503 to 406§
São Pedro	39	478	522	384	242	199	60	44§	141 to 74§
Tucum	45	147	487	451	341§				
Itirapina	46	100	731	631§					
Araquá	51	381	492	412	329	241			146 to 111§
Graminha	55	469	490	407	279	250	94	21§	
Alambarí	57	446	584	573	459	387	313	138§	
Floresta	63	274	505	443	266	231§			
Tucum	66	441	488	443	251	235			53 to 47§
Bocaina	69	147	549	402§					
Floresta	71	372	505	430	262	225	133§		
Sto. Antonio	79	293	528	—	333	297	235§		
Xarqueada	81	768	598	579	392	358	316	−170§	
Cascatinha	85	227	510	—	305	362	322	283§	
Sto. Antonio	90	473	528	—	333	301	171	55§	
Araquá	107	280	492	419	270	212§			
Araquá	112	627	492	478	295	223	136	−135§	136 to 32§
Araquá	115	140	492	418	352§				
Tucum Estadoal	1	758	487	432	281	231	66	−271§	66 to −8
Pitanga	—	460	580	—	—	—	—	120§	
Guarehy Estadoal	2	872	800	—	713	644	410	− 72	494 to 470§
Campinho Estadoal	4	281	620	—	494	467	339§		
Bofete	—	315	585	—	455	378	279§		
S. Pedro C.P.B.	1	817	543	443	305	272	39	−274	76 to 56 39 to −100
				STATE OF PARANÁ					
Rib. de Engano	6	389	575	—	—	—	431	186§	
Marechal Mallet	8	85	780	—	714?				714 to 695§
Carvãosinho	11	62	585	—	—	—	540	523§	
Rio de Peixe	17	265	540	—	—	—	445	275§	
Wences. Braz	23	61	800	—	—	—	778	740§	
Mar. Mallet	24	510	775	—	462	365	265§		
Ribeirão Pombas	35	126	580	—	—	—	527	454§	
Rio Claro	41	284	760	—	476§				
Barreiro	49	165	820	—	—	—	741	655§	
Mar. Mallet	52	518	775	—	407	324	?	257§	717 to 677
Campinho	54	174	738	—	—	—	629	564§	
Mar. Mallet	64	502	775	—	411	337	273§		724 to 682
Mar. Mallet	75	565	890	877	653	587	325§		549 to 492
Aff. Camargo	80	540	634	—	397	334	196	95§	546 to 478
G. Carneiro	103	43	500	458§					
Barbozas	108	123	749	—	—	—	684	626§	
G. Carneiro	113	38	500	462§					
Barbozas	117	323	750	—	—	—	648	428§	
São José	123	597	841	—	—	—	—	370†	703 to 690

* *D.F.*, derrick floor; *S.B.*, base of São Bento series; *E.N.*, base of Estrada Nova group; *Iraty*, base of Iraty group; *Tub.*, base of Tubarão series; *Itar.*, Itararé series.

§ Indicates that the well was abandoned in the formation at the elevation given.

† This well reached the base of Itararé at 471 meters, and to the final depth of 597 meters was cutting fossiliferous Devonian shales with diabase at the bottom of the boring.



BOLIVIA
MATO GROSSO
GOIÁZ
FUTURA CAPITAL FEDERAL
SÃO PAULO
PARANÁ
PARAGUAI
MI
TRES LAGOAS
PONTA PORÃ
CONCEPCION
S. PEDRO
ROSARIO
SAN ESTANISLÃO
CAMPO GRANDE
BAURÚ
BOTUCATÚ
CAMPINAS
CASTRO

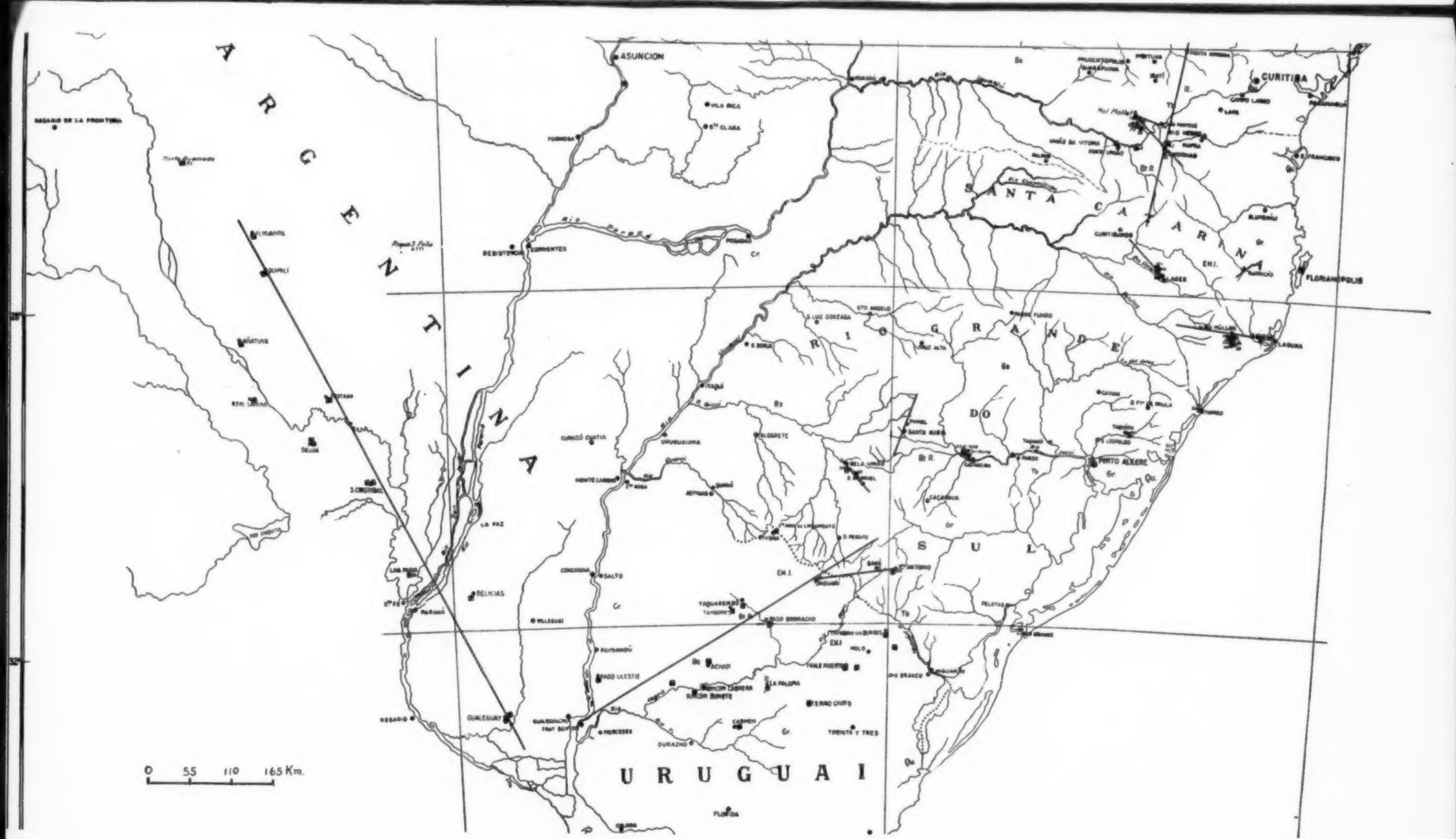


FIG. 14.—Map showing location of principal wells drilled for oil, or for other purposes, in Southern Brazil, Uruguay, Argentina, and Bolivia, between Lat. 20° and 34° S. Hollow square in State of São Paulo shows area of wells in São Pedro-Xarqueada (Fig. 13). Straight lines show locations of geologic cross sections illustrated in *Serviço de Fomento da Producção Mineral Boletim 5* (Brazil, 1934). Small solid squares show locations of wells.

MATO GROSSO
PARAGU
CAPITAL FEDERAL
GERAIS
BELO HORIZONTE
ESTADO DO RIO
NITERÓI
RIO DE JANEIRO

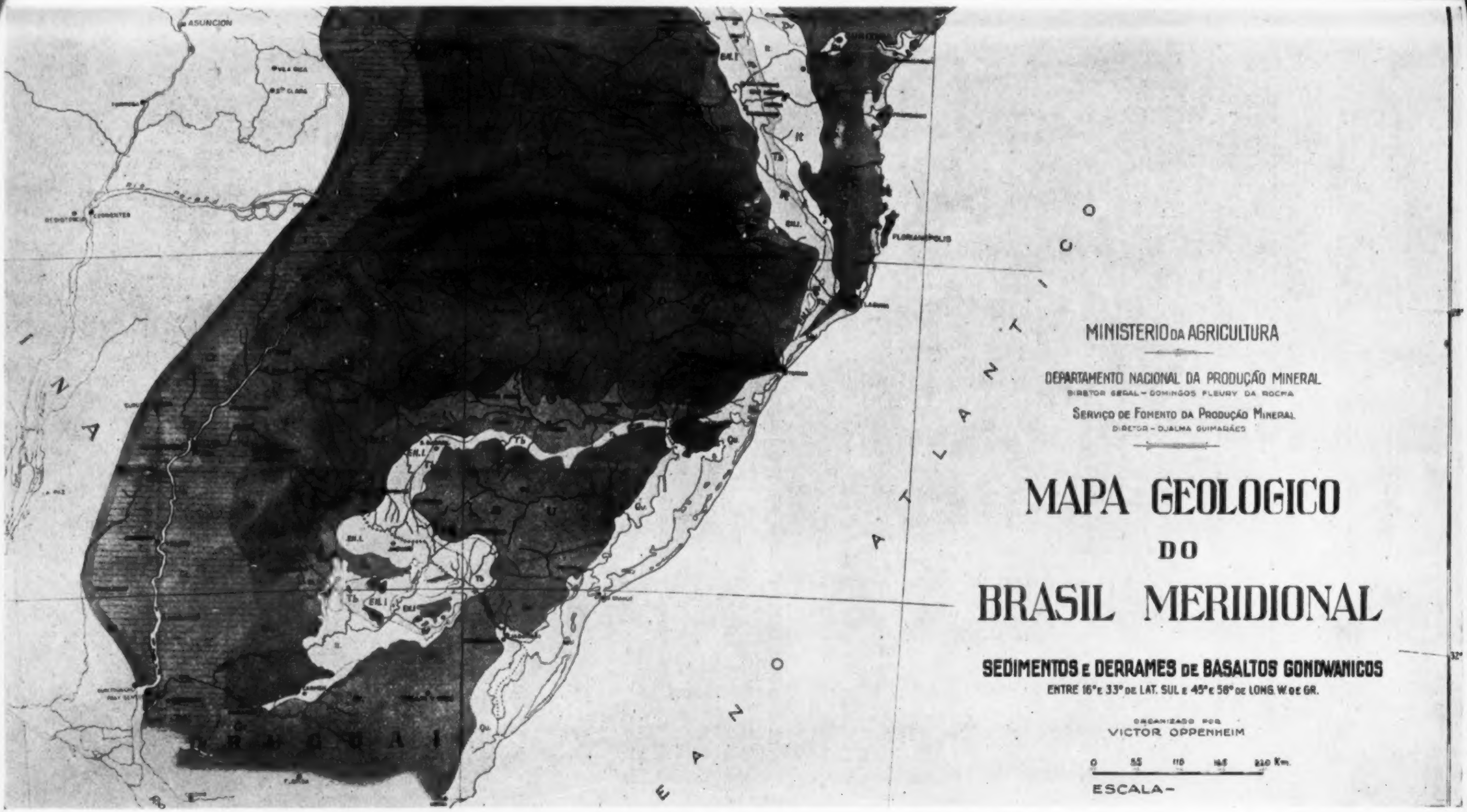


Fig. 15.—Geological map of Southern Brazil, showing Gondwana sedimentary rocks and traps between Lats. 16° and 33° S., and Longs. 45° and 58° W., Greenwich. *Gr.*, granite and gneiss (Silurian-Archean); *Dv.*, Devonian sedimentary rocks; all pre-Gondwana. *It.*, Itararé series; *Tb.*, Tubarão series; *EN I.*, Estrado Nova Inferior; all Permian. *Bt.R.*, Botucatú sandstone, etc. (Triassic); *Bs.*, basalts (Upper Triassic); all of São Bento series. *Cr.*, Cretaceous; *Qu.*, Quaternary; all post-Gondwana.

Original map in colors was published by Serviço de Fomento da Produção Mineral to accompany *Boletim 5* (1934).

TABLE IV (*Continued*)

Name of Well	*No.*	*Total Depth*	*Elevations* in Meters Above Sea-Level of Bases of*						*Diabases (Main Intrusions)*
			D.F.	*S.B.*	*E.N.*	*Iraty*	*Tub.*	*Itar.*	
STATE OF SANTA CATHARINA									
Rio Pio	4	532	161	—	61	?	−77	−343§	−343 to −371
Rio Dória	10	289	411	—	—	361			361 to 122§
Rio Mão Luiza	20	242	363	—	273	223	121§		
Rio Jordão	29	361	138	—	91	64	−223§		
Rio Fiorita	37	116	181	—	—	—	65§		
Praça Jordão	40	306	80	—	—	—	−226§		
Rio Mão Luiza	47	287	45	—	21	−8	−242§		
Rio Mão Luiza	53	275	287	—	—	260	34	12§	
Piedade	62	472	765	—	634	593	301	294§	
Valões	65	511	760	717	?	508	249§		508 to 447
Canoinhas	82	598	745	—	685	612	376	77§	
Lages	86	291	877	—	715	(Phonolite to 586 t.d.)			
Lages	116	500	820	671	437	331	320§		
STATE OF RIO GRANDE DO SUL									
Ferreira	2	32	33	1§					
Ferreira	3	97	33	−64§					
Ferreira	5	99	33	−66§					
Ferreira	7	221	33	−66	−160	−181	−188§		
Ferreira	26	284	33	−62	−233	−251§			−199 to −226
Torres	30	481	66	−211	?				−366 to −415
Taquara	44	497	29	−229	−421	−468§			
Bella Vista	59	240	150	—	85	−1	−90§		
Xarqueada S.A.	105	42	180	—	—	—	—	138§	
Bella União	121	206	125	58	−39	−81§			

structure of the whole is somewhat unusually homogeneous in most of its facies.

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Part II

Petroleum Geology

I. PETROLEUM OCCURRENCES IN GONDWANA ROCKS

In the first part of the present work, and as far as the known data would allow, we correlated the sediments of a genetic cycle, common in its principal features, and embraced by the conception of Gondwana rocks.

The considerable gaps in our present knowledge prohibit our determining the exact proportions of the past connection between the present continents of the Southern Hemisphere. However, without considering details of the development and subsequent dispersion of the Gondwana continent, there is undoubtedly a geogenetic and paleogeographic connection between the rocks which to-day form the continents of the Southern Hemisphere, in the geological eras of the beginning of the Permian and end of the Triassic.

With a view to making as complete a study as possible of the possibility of finding exploitable petroleum in the Gondwana sediments of Southern Brazil, and following the geologic correlation made in the first part of this work, we propose to make a brief review of the known occurrences of hydrocarbons, exploitable or otherwise, on the continents of the Southern Hemisphere. Brazil is studied in detail in the following section.

The following review is a summary of the most recent information—much of which has been published in the *Bulletin* of The American Association of Petroleum Geologists—concerning the occurences of petroleum in Gondwana rocks.

South Africa.—In several places in Cape Colony and Orange Free State there are sandstones which, in contact with doleritic eruptives, show bituminous impregnations; apparently, this is a feature identical with that observed in the sandstone of Botucatú, in Brazil. According to A. W. Roger and A. L. Du Toit, these occurrences are due to the distillation through the intrusives of the bituminous and carbonaceous rocks of the Karroo system. Gas has been found in several wells, generally in the vicinity of intrusives.

The "White band," which, according to Du Toit, is identical with the Iraty, did not show signs of petroleum accumulation. Geologically and paleontologically, the Santa Catharina system of Brazil closely resembles the Karroo, and it is noteworthy that intensive prospecting for petroleum in the latter area has given consistently negative results.

Madagascar.—Several active exudations are known in the western part of the island. These are derived from Tertiary deposits and, according to Wade, are the distillation product of the carbonaceous rocks of this age. Jurassic and Triassic beds containing as much as 10 per cent of bitumen exist in certain localities, and numerous wells drilled in this area yielded traces of gas and bitumen, which are, however, unexploitable.

Angola.—Traces of gas were found in the wells at Inhangaminga. In the district of Libolo there is being worked a deposit of asphaltite in a viscous or solid state, called libolite. This occurrence is related to the sandstones and Cretaceous conglomerates lying discordantly above the basement granites. Numerous perforations made by American interests have found only traces of unexploitable oil.

West, East, and Central Africa.—Traces of hydrocarbons have been located at Kilimoto, on the shores of Lake Albert Nyanza. Other traces are known in post-Triassic rocks in Kenya and British Somaliland; on the western coast, above Angola; and in the Cameroons, Gold Coast, and French Guinea. All these occurrences yielded nothing more than traces.

North Africa. Morocco.—Numerous wells found sporadic traces in the Miocene and Eocene rocks in the district of Gharb (Souk el Arba). The zones east of Morocco appear favorable for prospecting, but are not yet producing regularly.

Algeria and Tunis.—There is a small production of petroleum at Tlionanet, in Miocene rocks.

Egypt.—The considerable accumulations of petroleum at Gabel, Zeit, and Gemzah, on the coast of the Gulf of Suez, are found in Cretaceous rocks lying on basement granites.

In concluding the review of Africa, it should be noted that the only occurrences of exploitable petroleum are associated with Cretaceous rocks. The numerous wells drilled in the Karroo of South Africa have so far proved the non-productiveness of the Gondwana rocks, in spite of traces of gas and semi-liquid bitumen.

New South Wales.—At the top of the Permo-Carboniferous system, and immediately below the Triassic sedimentary rocks of the Hawkesbury system, there is a bituminous and carboniferous bed 3 meters in thickness, called the Bully seam. This bed resembles the Iraty in its nature and stratigraphic position. It is highly saturated with bitumen and has been partly exploited by distillation processes. No exploitable petroleum is found in connection with these rocks.

Queensland.—Seepages of liquid paraffine in artesian water have been found in the Cretaceous beds near Longreach; the prospecting for petroleum carried out as a result of these observations has so far proved negative.

West of Brisbane, gas escapes have been known for many years.

In the Permo-Carboniferous beds at Balmain, near Sydney, many interpositions of coal have been found. Drillings in this region have encountered combustible gases at a depth of 1,000 meters, though the gas is not commercially marketable. These beds may be the equivalent of the Tubarão of Brazil.

Western Australia.—South of Wyndham, and in the Northern Territory, 350 kilometers east of Port Darwin, semi-solid bitumen is found in cavities of diabases in association with quartzites apparently of Cambrian age.

New Zealand.—Petroleum in small quantities occurs in Tertiary beds more than 1,000 meters thick. These beds are connected with andesitic intrusives. Active seepage has been known here since 1905, the oil being chiefly associated with post-Miocene traps.

On the central plateau, at Waiotapu Stream, there are several exudations of petroleum and gas.

According to James Park, these hydrocarbons originate in the Tertiary coal which, with the sediments of the same age, occupy the whole of the central part of North Island.

New Guinea.—There are many signs of petroleum in the Tertiary beds. Nevertheless, although gas has been found at varying depths, oil in commercially available conditions has not been encountered.

New Caledonia.—At Koumac, in the northwestern part of the island, there are exudations from Eocene beds associated with posterior intrusives.

Sumatra, Java, and Sarawak.—The considerable accumulations of

oil in these districts are associated with Pliocene and Miocene shale beds. Part of these accumulations comes from intrusives, and part is associated with the intense diastrophism of the sediments.

Summing up the review of Australia and Oceania, we may say: (1) that the Gondwana rocks (Triassic and Permo-Carboniferous sediments), though showing traces of oil, gas, and coal, do not produce exploitable petroleum, and (2) that the only known exploitable occurrences are found in New Zealand and the Malay Archipelago, in association with Tertiary beds.

India.—The peninsula, or Hindustan, is the only area of Gondwana rocks in India. It is a peneplaned plateau composed of pre-Cambrian rocks covered by discontinuous beds of Permian and Triassic sediments. Structurally, it does not show facies of any considerable orogenesis; disturbance is slight, and it is characterized by zones of faults and grabens.

The occurrences of bitumen in basaltic cavities at Bombay are, according to C. S. Fox, of the Upper Cretaceous.

Gas appears in the littoral zone at Baroda, in association with Tertiary sediments.

Some traces of gas observed on the Madras coast and in Ceylon are related to the Upper Tertiary.

All the exploitable petroleum areas of northern, eastern, and western India evidently belong to Tertiary and Upper Cretaceous beds. Petroleum occurrences or even traces are not known in the Gondwana rocks of India.

South America.—It is well known that all the oil fields of the chief producing countries of South America, namely, Venezuela, Trinidad, Colombia, Ecuador, and Peru, are of Tertiary or Cretaceous age.

The following known data will suffice concerning petroleum occurrences in those countries in South America where Gondwana rocks are developed. As mentioned previously, Brazil will be studied in the following section.

Uruguay.—The writer's paper, "Petroleum Geology of Central Sedimentary Basin of Uruguay," published in the August, 1935, *Bulletin* of the Association, deals with this subject.

The numerous borings, many of which have traversed the whole sedimentary column of the Gondwana rocks, failed to find any significant traces of oil.

There are some Iraty shales and asphaltic impregnations in the "Areniscas de Tacuarembó," on the Brazilian frontier.

Argentina.—There are four main petroliferous areas: (1) Territorio de Chubut (Comodoro Rivadavia); (2) Territorio de Neuquen

(Plaza Huincul); (3) Provincia de Mendoza (Cacheuta and Sosneado); and (4) Salta and Jujuy provinces (Bolivian frontier zone).

Comodoro Rivadavia.—The petroleum is heavy, with an asphaltic base. It is generated in, and drawn from, the Chubutian and glauconitic floors, which are of Cretaceous age. Structurally, the zone presents characteristics of incompletely developed anticlines. The chief productive horizon occurs between 500 and 600 meters below the surface, the deepest well reaching the Lower Cretaceous at a depth of 2,200 meters.

Plaza Huincul.—The productive horizon is found between 600 and 700 meters below the surface, and is related to the rocks of the Upper Jurassic or Lower Cretaceous. The dominating structure is a monocline with local faults.

Province of Mendoza.—There are several exudations of heavy oil in the western part of the province and in the Pre-Cordillera, and the zone may be considered as semi-commercially productive.

The stratigraphic column consists of 4,000 meters of sediments lying discordantly above the basement. The age of the component rocks varies from Upper Jurassic, at the base, to Tertiary. Structurally, they are heavily fractured folds traversed by intrusive andesite.

The Jurassic sediments are capped by bituminous shales containing abundant fauna of pelecypods and cephalopods, though no plant remains have been found; while the shales are in turn covered by limestone beds of the Lower Cretaceous (Neocomian) age.

In most wells, the oil was found in the shale and limestone beds, although the true petroliferous horizon is probably constituted by the Cretaceous limestone beds. However, various geologists think that both horizons contributed toward the genesis of the oil, the process being possibly connected with the intrusive masses, the considerable thickness of the underlying rocks, and friction in the fault zones.

Salta.—The Pre-Cordillera zone in the northeastern part of Salta is very poor in fossil remains, thus rendering geological studies somewhat difficult. There are two probably petroliferous horizons, one being related to Cretaceous beds and the other to Devonian rocks. All the occurrences of petroleum in the neighboring area of Southeastern Bolivia have been found in Devonian rocks, and it may be assumed that the Devonian petroliferous horizon of the Province of Salta is a continuation of these beds and structures.

The predominating structure is one of well formed anticlines, extending for considerable distances along the Cordillera. These anticlines are narrow and steep-sided, many of them related to extensive

faults and fractures of regional character. Many active exudations are known in this area and in the neighboring Province of Jujuy.

The numerous wells drilled in Eastern Argentina, between Alhuampa and Gualeguay, the deepest of which reached 1,940 meters, have all cut through the Gondwana sediments, and have all failed to find oil, though traces were found in the Gualeguay area, probably related to the bituminous Iraty horizon.

Bolivia.—The three chief petroliferous areas of Bolivia are the following.

1. The Amazon zone, embracing the District of Beni and the Territory of Colonias. The area is composed of beds of Tertiary and Cretaceous sedimentary rocks of considerable thickness, the structure being one of anticlines occurring along the Cordillera, with fractures and faults indicated by active seeps.

2. The high plateau zone of Lake Titicaca, forming the continuation of the corresponding area in Peru. This zone includes the areas bordering the lake, with particular reference to the districts of Calacoto and Pacejas.

3. The central and southern zones of Eastern Bolivia, extending along the Pre-Cordillera from Santa Cruz to Yacuiba, on the Argentine frontier, and embracing the provinces of Chuiquisaca and Tarija. The petroliferous horizons occur in Devonian or Cretaceous rocks.

The principal structure is one of anticlines and faults. A series of anticlinal folds forms the Serra de Charagua in the north, and the principal anticline in the extreme south is that of Aguarague which penetrates into Argentina. North of Santa Cruz the folds of the Pre-Cordillera dip below the overlying beds of Cretaceous sediments.

The petroleum of the southern part of Bolivia is of two different types: there is a light, clear oil, with paraffine base, and there is an asphaltic oil which is heavy and dark. The first type is associated with the Devonian rocks, while the second is probably related to Cretaceous sediments.

Paraguay.—There are several occurrences of bituminous Iraty shales. Further traces of bitumen or oil have not been observed in the Permian or Triassic basin of Paraguay, or in the Paraguayan Chaco, on the west.

So far, no occurrences or pronounced traces of oil have been found in this country.

Conclusions.—The foregoing brief analysis of the areas of Gondwana rocks in India, the Southern Hemisphere, and South America serves to show that occurrences of commercially exploitable oil are unknown in those areas.

With the exceptions of Southern Bolivia, where the oil is related to Devonian rocks, and the Mendoza-Neuquen area, where it has not been decided whether the productive rocks are of Upper Jurassic or Lower Cretaceous age, all the known productive rocks in the areas analyzed are of Tertiary or Cretaceous age.

All the occurrences are related to definite types of structure. The areas with zones of dislocation, or traversed by intrusives, invariably show numerous active seeps.

Although some of the bituminous Gondwana rocks of South Africa, Madagascar, Australia, and New Zealand show a high percentage of bitumen, these rocks are not exploitable under present economic conditions.

The beds containing *Glossopteris* flora and coal seams contain gas and traces of oil, but nowhere are they known to be sources of exploitable petroleum.

In spite of the huge area covered by Gondwana rocks in the Southern Hemisphere, the favorable geological structure of fractures or association with intrusives, and the large number of deep borings made in various countries, no active seeps or accumulations of exploitable petroleum have so far been found.

II. HYDROCARBONS IN GONDWANA ROCKS OF SOUTHERN BRAZIL

REVIEW OF SEDIMENTARY CYCLE OF SYSTEM

The geological history of the sediments reveals facies which permit us to outline the probable chrono-geologic origin of deposition.

Lower Permian.—1. Sandstones, varve-clays, and shales of glacial deposition of the Itararé series were probably deposited from ice sheets floating in standing water, or were deposited in epi-continental seas, during a period followed by more continental facies of deposits with striated boulders, tillites, et cetera.

2. Sandstones and shales with coal seams and the remains of an abundant *Glossopteris* and *Gangamopteris* flora of fluvial deposition followed the final retreat of the ice sheets, and formed the Bonito and Palermo sediments of the Tubarão series.

Upper Permian.—1. The bituminous, calcareous black shales, with *Mesosaurus* remains, of the Iraty group, are supposedly of epicontinental lacustrine or seashore deposition. The margins of the Iraty basin apparently embraced the present-day territories of Paraguay and the State of Goyaz on the west, Uruguay on the south,

and the State of Minas Geraes on the north. The sediments of the "White band" of South Africa prove that the western limit of the Iraty beds was in Africa. Apparently, the sea of that time gradually receded during the second half of the Permian age, aquatic sedimentation being followed by terrigenous deposition.

2. The sandstones and gray shales, intercalated with lenticular beds of calcareous rocks of the Lower Estrada and yielding remains of *Glossopteris* flora and petrified wood, demonstrate that they are terrigenous deposits, with local lacustrine conditions. The deposition of this group marked the close of the Permian cycle.

Presumably, a hiatus separates those sediments from the overlying beds of the Upper Triassic that followed the Permian deposits. Although not visible, the discordance evidently exists stratigraphically and paleontologically.

Triassic.—1. The shales, clays, and red, yellow, or variegated sandstones of the Upper Estrada are chiefly terrigenous, although the comparatively slight thickness of the Rocinha limestones, and the beds with *Myophoria* and *Pachycardia* mollusks show that at the beginning of this period there were sporadic and short-lived marine ingressions in the predominating continental formations.

2. The sandstones and red clays of the Rio do Rasto mark the definite advent of continental terrigenous deposition. Locally, the sedimentation shows a hiatus with discordance above the Upper Estrada Nova of the Passo Dois series.

3. The São Bento series began with the deposition of the Rio do Rasto, and shows well marked eolian and typically desert facies in the Upper Triassic Botucatú sandstones.

The sedimentary cycle ended with the formation of large traps of basaltic lavas both contemporary with, and subsequent to, the Botucatú sedimentation. The effusive process caused intense diastrophism throughout the system. The basalts formed an important bed covering the greater part of the sedimentary basin of Southern Brazil.

Sandstones, probably Rhaetic, were deposited in small agglomerations in the western part of the State of São Paulo, above the trap; these are the Caiuá sandstones.

Cretaceous and Tertiary sediments of terrigenous origin cover the eruptives of the Serra Geral, in the extreme western part of the trap. They are poorly developed and show an evident hiatus. Similar sediments occur sporadically in small basins above the metamorphic rocks of the Serra do Mar.

STRATIGRAPHIC DEDUCTIONS

The thicknesses of the various beds composing the sedimentary system are approximately as follows.

	Meters
Itararé series	500–700
Tubarão series	100–250
Iraty group	40– 70
Passa Dois series (excluding Iraty group)	100–200
São Bento series	150–250

Due to the enormous area covered by the sedimentary basin, the various horizons of the system vary considerably in thickness from region to region. However, on the basis of observations of outcrops and drilling, we can assume a total thickness of about 1,500 meters for the Gondwana sediments of the Santa Catharina system in Southern Brazil.

The intrusives are well developed, and since they lie in close contact with the sediments, it is possible that the Gondwana column may be even thicker.

The Iraty group is the only formation in the system that could be considered as a source of petroleum, and the known traces of oil in the system should be attributed to this group. Neither the glacial sediments of Itararé, nor the later beds of Tubarão, appear as possible sources of petroleum, because of their negative characteristics of composition, sedimentation, and deposition. In this respect the writer agrees with the observations made by Washburne and other authors.

On the other hand, the Permian and Triassic sediments of the Estrada Nova and São Bento series also lack the characteristics indispensable for originating and developing a petroleum source bed. These sediments are terrigenous, with eolian, desert facies.

The bituminous impregnations of the São Bento sediments are presumably due to bitumen brought up by the waters of the Iraty horizon. It is difficult to account otherwise for these occurrences in such a typically eolian formation as the Botucatú sandstones, where such impregnations are known in a few outcrops.

Consequently, in the whole of the Santa Catharina system, the only rocks which can be considered as presenting characteristics favorable for the formation of petroleum are those of the Iraty group of the Passa Dois series.

We shall now analyze the characteristics of this horizon as deduced from observations of outcrops and the detailed examination of logs and cores of wells in various places in the Paraná Basin, also taking into account the bibliographic material and observations of various previous authors.

OCCURRENCES OF HYDROCARBONS IN ESTRADA NOVA GROUPS AND SÃO BENTO SERIES

No active oil seeps are known in Southern Brazil or in the adjacent territories of Uruguay, Paraguay, or Eastern Argentina (Argentine or Paraguayan Chaco). All superficial occurrences are limited to bituminous shales, asphaltic impregnations in limestones, bituminous sandstones, and bitumen in vesicles of intrusives.

The numerous outcrops of bituminous shales with limestones of the Iraty group were mentioned in Part I. The percentage of bitumen content, and the occurrences themselves, are discussed later.

Bituminous sandstones are known, and were also observed by the writer in many outcrops. They occur sporadically in the São Bento series in the following places in the State of São Paulo: Porto Martins, on the Tieté River, where the beds show uneven impregnation, and at Bofete, where there are several outcrops.

The bitumen found in the Bofete area was analyzed by White (13), with the following result.

	Percentage
Petrolene	9.82
Asphaltene	3.18
Organic matter	3.54
Fixed mineral matter	83.46
Sulphur	5.20
Nitrogen	0.51
Loss at 50°	0.25

The aforementioned occurrences are the chief ones. There are other impregnations, apparently of the same nature: at Alambarý, west of Botucatú; at Bairro do Kerosene; at Graminha, at São Pedro; and in a few other places recorded by Moraes Rego, all in the State of São Paulo. No other sandstones with the same characteristics are known in the remaining states of the south. There is apparently an occurrence of the same type in the Department of Tacuarembó, in Northern Uruguay.

As has already been suggested by various geologists, it is probable that these impregnations are connected with the intrusives, the process of distillation of the Iraty shales being followed by migration of the oil along the intrusives and zones of metamorphic contact until it reached the surface. The present relationship observable between the impregnations and the intrusives supports this theory.

Sporadic occurrences of fragments of albertite were noted in some places in the states of Paraná and Santa Catharina; they are probably related to the albertites found in the Iraty shales.

E. de Oliveira mentions occurrences of albertite near the town of Rio Claro, in the State of Paraná. An analysis of this albertite gave the following result.

	Percentage
Humidity	1.53
Volatile material	70.60
Fixed carbon	26.39
Ashes	1.48
	100.00
Sulphur	1.1

In conclusion we shall mention the occurrences of bitumen in intrusive and extrusive basaltics in various places in the states of Southern Brazil. Occurrences have been observed by Baker in Santa Catharina and São Paulo; they are also known near Capinzal (State of Santa Catharina) and were observed by the writer at Condoy, west of Guarapuava, in the Iguassú River valley. The occurrence of bitumen in these effusives may be explained as due to the contact of vesicular basaltics in an igneous state with the bituminous shales, causing distillation of the bitumen. In the absence of the oxygen necessary for combustion, the gases from the bituminous material condensed in the vesicles of the intrusives with the colling of the latter. Similar occurrences of bitumen in the intrusives of Panuco, in Mexico, may be attributed to the same process.

Apart from the aforementioned, there are no other known occurrences in Southern Brazil which can be related to the rocks of the Santa Catharina system.

In this paper we do not propose to deal with the local appearance of pyro-bituminous shales, related to Tertiary sediments, at Taubaté. Tertiary and Cretaceous beds in Southern Brazil show very little development and are distinctly terrigenous. These sediments need not be considered as far as petroleum geology is concerned.

IRATY AS PETROLIFEROUS HORIZON

As previously mentioned, the Iraty group of the Passo Dois series forms a bituminous horizon of considerable extent. Many outcrops of bituminous shales and asphaltic limestones of the Iraty group are known in São Paulo, Paraná, Santa Catharina, and Rio Grande do Sul, and some have also been observed in the southern part of Goyaz, and in Matto Grosso, Uruguay, and Paraguay. The thicknesses of these beds varies considerably, but the average is between 40 and 70 meters.

Lithologically, the Iraty is composed of black shales with thin intercalations of limestones and chert. When broken, most of this material gives forth a smell of petroleum. The cavities and fissures in many outcrops and well cores appear filled with bitumen or its oxidized residue—albertite, grahamite, et cetera.

We give below the analyses of the Iraty material, as cited in I. C. White's report.

	I	II	III
Humidity	3.95	0.35	1.58
Volatile matter	19.40	41.15	5.35
Fixed carbon	8.91	57.33	76.27
Ash	67.74	1.17	16.37
	100.00	100.00	99.57
Sulphur	5.68	16.00	2.09
Phosphorus	0.06	0.01	
Carbon	16.36	68.19	
Hydrogen	3.67	7.22	
Oxygen	8.22	5.91	
Nitrogen	0.50	1.51	
Sulphur	3.51	16.00	
Ash	67.74	1.17	
	100.00	100.00	
Petrolene	7.30	4.44	
Asphaltene		6.80	
Non-bituminous organic matter	24.96	87.59	
Ash	67.74	1.17	
	100.00	100.00	
B.T.U. calorimeter	—	14,567	
B.T.U. calculated	—	14,483	

I. Iraty black schist from a well near Bella Vista, in Rio Grande do Sul.
II. Albertite of Iraty black schist near Lages, State of Santa Catharina.
III. Natural coke from the Iraty black schist horizon near Limeira, State of São Paulo.

The lack of more complete chemical analytical data does not allow us to make positive and generalized correlations between the various outcrops of this extensive horizon. Nevertheless, the constancy of the chemical and lithological characteristics of outcrops in a belt 1,500 kilometers long and embracing all the typical structures of the region, renders it possible to make deductions of a general nature.

The apparent genesis of the Iraty in a shallow and highly saline epi-continental or lacustrine sea favored the existence and development of organisms and micro-organisms in which originated the bituminous material. The generic conditions are thus favorable for assuming the Iraty as the source rock of the bituminous material and heavy oil found to date.

The following is the result of an analysis of bituminous shale made by the Section of Mineralogy and Petrography of the then Geological and Mineralogical Department of Brazil.

No. 68. Schist from Tapéra, Municipality of Angatuba, State of São Paulo
Distillation furnished:

	Percentage
Oil	8.35
Water	4.00
Residues	78.00
Gases and losses	9.65

Volume of gas—31,832 cubic meters per ton
Analysis of gas:

	1st Fraction	2nd Fraction	3rd Fraction
CO_2	8.8	9.8	4.9
H_2S	7.7	11.0	7.5
C_nH_{2n}	7.1	6.5	1.2
CO	1.0	0.6	3.2
O	1.6	0.0	0.0
CH_4	4.63	55.6	39.9
H	6.4	3.0	28.7
A_2	21.1	13.5	14.6
	100.6	100.0	100.0

Second oil fractioning:

	Percentage	
Fraction up to 150° (gasolene)	0.40	
Fraction from 150° to 200° (kerosene)	8.10	Density 0.829
Fraction from 200° to 250° (light oils)	10.00	Density 0.891
Fraction from 250° to 300° (medium oils)	46.60	Density 0.917
Residues and losses	34.90	
	100.16	

Analysis of ash: residue from distillation of schist gave loss in heating of 12.40 per cent, an analysis of calcinated residue giving following result:

	Percentage
Silica	64.90
Alumina	16.36
Iron oxide	9.66
Manganese oxide	0.58
Lime	1.35
Magnesium	0.32
Sulphuric anhydride	0.89
Sulphur	0.43
Potassium	1.49
Soda	2.28
	100.16

Djalma Guimarães

Although it is theoretically possible to consider the Iraty as a matrix for petroleum, it must be borne in mind that this does not imply the presence of accumulations of petroleum. The Iraty merely provides one of the conditions favorable to such accumulations. As is well known, the presence of bituminous shales does not constitute a particularly favorable indication of the existence of exploitable petroleum.

GENESIS OF IRATY OIL

Considering the Iraty sediments as a matrix of the bitumen and heavy oil found in the Permian and Triassic rocks of the Santa Catharina system, three possible originating processes are open to examination.

1. The formation of bitumen and petroleum could be effected under pressure from the rocks overlying the Iraty. However, it is clear that the sediments of the Estrada Nova and São Bento series, with a total thickness of 300–400 meters, could not exert the pressure necessary to raise the temperature to a point sufficiently high to induce distillation of the organic matter and separation of the bituminous material from the matrix. In point of fact, there are no known instances of petroleum accumulations under such shallow beds.

2. Stratigraphic and tectonic observations have proved that the sediments of the system have not suffered folding or orogenic structural movements since their deposition at the beginning of the Permian. Neither the inter-Permian disturbances which affected the beds of the Sierra de Buenos Aires and the Pre-Cordillera, nor the extensive folding of the Andes affected the Santa Catharina system. Consequently, the Iraty was not affected by orogenic forces in the sense of a dynamo-metamorphism capable of producing petroleum.

3. There remains the hypothesis advanced by E. Oliveira, C. L. Baker, and C. W. Washburne, of the creation of the bitumen and asphaltic petroleum of the system by thermal action of the intrusives. The writer agrees with these authors that this theory is admissible as regards the Iraty bituminous shales. The Triassic intrusives undoubtedly exercised an intense geo-thermal action on the organic sediments of the Iraty, metamorphosing them into bituminous shales. It appears to us that this hypothesis is substantiated by the constant association of Iraty shales with intrusives, ranging from occurrences of shallow basaltic beds interpolated in the sediments to considerable sills which locally completely take the place of the horizon. The constant occurrence of albertite, grahamite, and coke-like bitumen observed in nearly all the wells in the Iraty and in the numerous outcrops mentioned by various geologists, proves that the Iraty suffered intense thermal metamorphism, probably throughout the whole area.

Observations show that in several places the intrusives were partly or wholly destructive, and that metamorphosis of the sediments was severe. It therefore seems improbable that accumulations of petroleum in any quantity could exist in the same horizon. If there existed petroleum formed in the Iraty horizon, it would inevitably

have migrated, either to the sedimentary beds of the Estrada Nova or Rio do Rasto, or to the lower sedimentary beds. However, in spite of the existence of considerable eroded and uncovered rock areas, both above and below the Iraty, in which petroleum should have accumulated, the complete absence of oil seeps in an area of more than 1,500 kilometers occupied by outcrops of sediments related to the Iraty, taken in conjunction with the absence of oil in the numerous wells, discredit any suggestion of a large-scale migration of oil originating in the Iraty sediments. Apparently, this migration resulted in nothing beyond the traces of oil and gas found in some wells drilled in beds overlying or underlying the Iraty. Yet the structural features of the system, as described in Part I, should be favorable to the migration and intercommunication of oil, if such existed. The many intrusive and extrusive bodies which traverse the system would provide an outlet for the petroleum and gases, while the numerous faults and fractures would serve the same purpose if there were really any accumulations of liquid or semi-liquid petroleum.

The Cretaceous petroleum beds of Mexico, and in particular the productive fields of Furbero and Panuco, yield hundreds of active seeps in contact with the outcropping intrusives or faulted areas—this in spite of the association of the beds with intrusive rocks on a much smaller scale, and over an incomparably smaller area, than occurs in Brazil. Wherever productive oil fields are associated with intrusives, active seeps are found.

Taking the Iraty as the only horizon capable of providing a matrix for petroleum and bitumen, we are led to conclude that this oil did not migrate from that horizon, nor did it accumulate in any quantities in the overlying sediments.

The distillation process of the bituminous sediments of the Iraty through the action of the intrusives was consequently limited to partial thermal metamorphism of the shales, or sporadic concentration of bitumen and small quantities of heavy oil in the cavities and fissures of that horizon and in the beds immediately above and below it. The special features of the Iraty lead us to presume that the organic material of this horizon was unsuitable for the creation of large quantities of petroleum. In support of this supposition it may also be mentioned that the analogous sediments of the "White band" of the Karroo system also show no evidence of petroleum accumulations. The same can be said as regards the coal measures of Australia.

TRACES OF OIL IN BORINGS

Hydrocarbons in beds above Iraty.—As is to be expected from the bituminous character of the Iraty, most of the wells drilled through

this horizon furnished cores impregnated with bitumen or oil. The traces found in the beds above and below the Iraty have evidently been transported by subterranean water along the faults, fractures, and intrusives which characterize the system, or, less probably, may be due to the local movement of the partly distilled oil of the Iraty shales. The appearance of gas in some wells outside the bituminous bed of the Iraty should be attributed to the same causes. It seems obvious to the writer that the traces of hydrocarbons in the beds under discussion are not syngenetic, and that they belong to material derived from the Iraty.

The following is a list of wells in Southern Brazil where traces of bitumen or oil were found above the Iraty.

Well	*Depth at Which Oil or Bitumen Found (Meters)*
State of S. Paulo	
Graminha 22	15
Kerozene 28	74
Santa Maria 32	188
Araquá 51	82
Tucum 66	245
Tucum Estadoal 1	245
Balloni	52
State of Paraná	
M. Mallet 52	35
M. Mallet 64	41
Aff. Camargo 80	51
State of Sta. Catharina	
Piedade 62	114

The more liquid oil is found chiefly in cavities or fissures in calcareous beds, and the more polymerized or solid bitumen occurs mainly in fissures and fault planes.

A detailed analysis of oil taken from the Araquá well was made by the Central Laboratory of Analyses of Rio de Janeiro (Analysis No. 1,113). The analysis makes it evident that the oil corresponds with the Iraty horizon.

Hydrocarbons in beds below Iraty.—A considerable number of wells drilled in the states of the south penetrated the Lower Permian beds of the Tubarão and Itararé. Some of these wells encountered sporadic oil and gas in these beds. Unfortunately, the traces found were not analyzed. However, our knowledge of the nature of the occurrences enables one to arrive at certain positive conclusions.

State of São Paulo.—In the Graminha well No. 22, bitumen was found in the Tubarão shales at a depth of 285 meters. The occurrence may be attributed to migration from the overlying Iraty.

In the Xarqueda well No. 81, traces of oil were found in the Itararé beds at a depth of 644 meters. The occurrence of oil in the glacial

sediments proves the migration of the bitumen from the lower Iraty horizon.

E. B. Dutra, in charge of the Tucum well No. 1, described the occurrence of traces of oil and gas in a detailed report extensively quoted by Washburne. Traces of oil were found in the Estrada Nova at a depth of 167.47 meters, and in the Iraty at 237 meters. Water and gas were found at a depth of 250 meters. In the Tubarão sandstones, below the Iraty and at a depth of 314 meters, further and larger quantities of gas were found in association with water bearing brownish oil stains (verbal information from Dutra). The oil was examined at the Polytechnical School of São Paulo, and was found to contain a small percentage of asphaltic residues. At 365 meters still larger quantities of gas were found, in light-colored pyritic sandstone. This well reached a depth of 758 meters and was abandoned in the glacial tillites. It penetrated several limestone beds, and at 421 meters struck a bed of diabase 74.60 meters thick.

Although the appearance of the traces of oil found in this well differs slightly from the bitumen of the Iraty, it seems to us that, in common with the other occurrences, it should be considered as related to the Iraty, particularly when it is remembered that only 59 meters of a greenish limy sandstone separated the occurrence from the Iraty horizon. The assumed lighter color of this oil is probably due to the process of purification and filtration to which the oil was subjected in its passage through the aforementioned sandstone bed.

The absence of traces of oil in the remaining 400 meters of the perforation, and particularly its absence in the intrusives underlying the occurrence, indicates a close connection between the traces of oil found and the Iraty horizon.

Washburne[4] mentions that at the Bofete well, at a depth of 500 meters, he was shown cores impregnated with a light greenish oil. This observation was not made during the drilling process, and differs radically from I. C. White's description of oil found in another well in the same zone. A description of the column traversed at the latter well is made in pages 32–34 of White's report.

State of Paraná.—In the Marechal Mallet well No. 75 asphalt was found at a depth of 309 meters in a fissure in the Tubarão sandstone, traces of oil being found at various depths down to 331 meters in small faults. The occurrences in fissures and small faults is particularly significant, as confirming the character of similar occurrences in the State of São Paulo.

[4] See Chester W. Washburne's comment in his review of Oppenheim's *Boletim 5* (*Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 11, November, 1935), pp. 1701–06.

State of Santa Catharina.—In the Piedade well No. 62, impregnations of petroleum were found at a depth of 245 meters, in the Tubarão shales.

Bituminous material was encountered in the Canoinhas well No. 82 in shales and sandstones of the Tubarão at depths of 324–382 meters. At 402 meters, and at various depths down to 666 meters bituminous material was found in the Itararé sandstones, while combustible gas in association with salt water was found at a depth of 683 meters, still in the Itararé sandstone. An examination of the complete and well preserved well cores showed the presence of bituminous material in isolated spots of the rock. This material is similar to the hydrocarbons in the Iraty.

No traces of oil or gas were found below the Iraty in wells drilled in the State of Rio Grande do Sul, and none in the many perforations made in Uruguay. These borings penetrated the Tubarão and Itararé beds to the basement rocks.

Traces of oil have been found in the well recently drilled at San Cristobál, in the Entre Rios Province of Argentina. This is the sole occurrence in the several deep borings made between Alhuampa and Gualeguay. It should be noted that one of these wells reached a depth of 2,100 meters, and it therefore seems probable that the occurrence is related to the presence of the Iraty horizon in the substrata of that area of the Paraná Basin.

In concluding this review of the occurrences of oil below the Iraty horizon, it should be noted that no evidence has been found of possible or probable petroliferous horizons in the wells or outcrops of the Permian sediments underlying the Iraty. All the verified occurrences must be attributed to oil derived and migrated from the Iraty horizon.

No verified analysis is known of the occurrence of a "light, green oil" which could be attributed to beds below the Iraty.

OCCURRENCES OF GAS

The occurrences of small quantities of gas in various borings, notably in that at Tucum in the State of São Paulo, are closely related to the bituminous shales of the Iraty and to the appearances of oil above and below that horizon. Presumably, these gases are the distillation product of oil which migrated from the Iraty shales to other horizons. The gases may have been generated in the initial process of distillation, as a result of thermal action of the pyroclastics, or by a subsequent process of disaggregation of hydrocarbonated elements produced by the same thermal action and by the pressure of the rocks overlying the hydrocarbons, which may or may not have been polymerized.

It is necessary to mention that the gases observed occurred in the form of passive emanations and that, in general, they were related to aqueous horizons.

Gas has been found at the following places and levels.

Well	*Depth in Meters*	*Manifestation*
STATE OF SÃO PAULO		
Araquá 51	310	Small amount of combustible gas in association with artesian water
Graminha 55	319	Artesian salt water with some gas
Tucum 66	—	Gas in increasing quantities, from 268 to 432 meters, in association with water from 371 meters downwards
Araquá 112	275	Gas in association with gray shales
	432	Larger quantity of gas and some water
	470	A little gas and some slightly saline artesian water
Tucum 1	350	Water and small bubbles of gas
	365	Pyritic sandstone yielding a volume of 4,200 liters of gas per hour

The last-mentioned occurrence is the most important of all those recorded.

In the State of Paraná, in the Affonso Camargo well No. 80, incombustible gas was observed at depths of 51 and 85 meters.

In the State of Paraná, combustible and sulphidic gas was found in the Canoinhas well No. 82, at 683 meters.

The gases in some of the foregoing occurrences were found to be combustible. The few analyses relating to these gases refer to the Tucum No. 1 and Graminha No. 22, and to the Rio Claro well, in the State of Paraná. Most of the gases are incombustible. Some analyses made in the laboratory of the Geological Service gave the following results.

SÃO PEDRO WELL, STATE OF SÃO PAULO

	Percentage
CO_2	1.2
O	1.0
CH_4	78.5
C_2H_4	2.4
N	16.9

Density of gas: 0.649. Calorific value: 7,067 calories per cubic meter.

GRAMINHA WELL, STATE OF SÃO PAULO

	Percentage
CO_2	Nil
O	0.3
CH_4	71.0
N	28.7

Density of gas: 0.674. Calorific value: 6,149 calories per cubic meter.

MARECHAL MALLET WELL, STATE OF PARANÁ

	Percentage
CO_2	1.00
O	1.01
CH_4	67.39
N et cetera	30.6

It is obvious from these analyses, and particularly from the percentages of CH_4 and CO_2, that these gases have a common origin. Gases of this composition can be derived from the distillation of oil, as already described.

The analysis of the gases obtained from distillation of the coal at Urussanga, in the State of Santa Catharina, shows that they have no apparent connection with those already mentioned. The following analysis of gases obtained from distillation of this coal supports this conclusion.

	Fractions		
	I	*II*	*III*
CO_2	27.3	2.7	2.6
Ethylene	4.1	1.7	0.0
CO	0.0	0.0	0.0
O	0.8	0.0	0.4
Methane	31.5	60.2	33.0
Ethane	17.0	0.0	0.0
N	0.0	11.9	48.5
H	19.3	23.5	15.5
	100.0	100.0	100.0

Fraction *I* at low temperature, fractions *II* and *III* at high temperature.

The limestones distributed throughout the systems might have influenced the formation of gas, and we therefore give the following analysis of distilled limestone from Tapéra, in the State of São Paulo.

	Fractions			
	I	*II*	*III*	*IV*
CO_2	71.2	87.8	71.7	41.9
C_nH_{2n}	7.0	0.0	0.0	0.0
CO	7.4	7.5	20.4	40.7
O	1.6	1.0	1.2	1.8
CH_4	3.6	0.8	1.0	1.8
N	12.7	2.1	5.3	13.8
H	3.5	0.8	0.4	0.0
	100.0	100.0	100.0	100.0

Analysis of the limestone: treatment by solvents yielded 0.11 per cent asphalt.

SiO_2	0.92
Al_2O_3	0.82
FeO	1.40
MnO	0.12
CaO	30.54
MgO	19.97
Loss in heating	45.93
P_2O_5	Nil
S	Traces
	99.70

Djalma Guimarães

Incombustible gases with a high *CO* ratio can be derived from limestones, either by action of igneous rocks in provoking calcination

with release of CO, or as a consequence of the dissolution of the beds by subterranean acid waters.

UNDERGROUND WATERS

Nearly all the wells drilled in the sedimentary belt found underground water at varying depths. Most of the water is apparently meteoric or artesian, this being particularly so in the case of the beds overlying the Iraty. In the porous sandstones covered by the shales and clays of the Rio do Rasto and Estrada Nova beds there are many reservoirs of these types of water.

The topographic features of the sedimentary area between the Serra do Mar in the west and the Serra Geral in the east render this zone an ideal receptacle for the waters of the heavy rainfall of these latitudes. The porosity of the beds and the fractures and fissures produced by the intrusives allow the meteoric waters to penetrate into the sedimentary layers. Nevertheless, the base of the Passa Dois series may be considered as being, in a general way, the probable limit of penetration of such water.

From observation of the wells and study of the logs it is found that salt water under fair pressure occurs immediately below the Iraty horizon in the majority of borings made in that horizon. The water is generally associated with marine deposits, especially in the Santa Catharina sediments, where saline concentrations which could have saturated the water with salts are not known. It seems obvious that this water formed the neritic epi-continental sea of the Iraty, and that it was buried with the sediments of that group. The pressure observed can be attributed to the heavy bed of shales and limestones under which the water is imprisoned.

There are very few analyses of this water. That reproduced here was made by Mario Pinto at the Central Laboratory of Analyses, from water found in the well at Alambary, in the State of São Paulo.

	Grammes per Liter
Residue at 110°	3.1305
Residue at 180°	3.1205
Fe_2O_3 and Al_2O_3	0.0028
Ca	0.0042
Mg	0.0092
Na	1.0350
K	0.2525
Li	Nil
Cl	0.8775
Br	Nil
I	Nil
SO_4	0.2415
HPO_4	Nil
SiO_3	0.0177
CO_2	0.5162

It will be seen that this water contains all the elements common to marine water. The absence of *Br* may be considered as fortuitous and due to some process of mineral absorption and dilution. Similarly constituted water has been found at lower depths, in the Tubarão and Itararé.

An analysis of water found in the Tucum well No. 1 at a depth of 214 meters was made by the Central Laboratory of Analyses and gave the following result.

	Grammes per Liter
Residue at 110°	1.6736
Residue at 180°	1.6664
Fe	0.0084
Al	Traces
Mn	Traces
Ti	Nil
Ca	0.0038
Mg	0.0166
Na	0.6290
K	0.0240
Cl	0.6931
Br	Nil
I	Nil
NO_2	Nil
NO_3	Traces
HS	Nil
SO_4	0.0008
SiO_2	0.0138
HPO_4	Nil
CO_2 total	0.3282
Mineral nitrogen as NH_3	0.00064
Organic nitrogen as NH_3	0.00044
Mildly acid organic matter	0.00720
Mildly alkaline organic matter	0.00408
Free H_2S	Nil

This water is analogous in composition to that of Alambary, and is likewise of marine origin.

It is evident that the presence of this water in fluvio-glacial or lacustro-glacial sediments can not be related to those sediments, and it is to be presumed that the water migrated from the Iraty horizon. Such migration would be greatly facilitated by the structure of the Iraty. The waters found in the system have apparently no genetic relationship with the known traces of oil, though they probably served as a means of transport for the bituminous particles found below the Iraty.

A sulphurous water with a variable percentage of mineral matter is found in many wells and localities in the sedimentary belt, as well as in the area of the eruptive plateau. An analysis of this type of water, taken from the neighborhood of Guarehy, in the State of São Paulo, gave the following result.

	Grammes per Liter
PO_4	0.01307
SO_4	0.23712
CO_3	0.07902
SiO_2	0.00174
SO_4	0.05714
Cl	0.01097
Na	0.25810
K	0.00270
Li	0.00018
Ca	0.09161
Al and Fe	0.00140
Permanent alkalinity	0.0837
H_2S per liter	10.54 cc.
CO_2 per liter	9.09 cc.

This type of water is particularly common in the zone of the traps, and commonly has certain medicinal properties. It is of magmatic origin and was produced, either by a synthetic process during the cooling of the magma, or by contact of the magma with meteoric waters of the sediments. Many occurrences of this water are associated with thermal waters.

Concluding this retrospect of occurrences of underground water in the system, it appears to the writer that, apart from the Iraty beds, there are no aqueous horizons in the Santa Catharina system which could be considered as related to occurrences of oil traces in the sediments.

RELATION OF STRUCTURES TO HYDROCARBONS IN THE SYSTEM

As was demonstrated in Part I, two tectonic features predominate throughout the system.

1. The magmatic intrusions, occurring in numerous outcrops, eroded protuberances or conspicuous domes, as well as being known in almost all the borings. These intrusions profoundly affected the sedimentary beds.

2. The sediments of the system were intensely broken by faulting, fracturing, and dislocation. The faults are not visible on the surface, owing to deep peneplanation of the area, but positive evidence of severe movement is plentiful, and is shown by: (a) contiguous wells in several separate zones, which strike the Iraty horizon at varying depths, the beds being horizontal; (b) the large number of cores, from many borings, which demonstrate dislocations of the strata and intense fissuring; and (c) the fact that many of the cores show fissures lined with calcite, or zones of breccia.

Dislocations are most intense in the Permian sediments (Iraty and lower horizons). Dislocations and faults are less observable in

the overlying Triassic beds, this being possibly due to the homogeneity of the sediments.

In the Triassic sediments, overthrust faults probably predominate since, in the lower beds, the faults show a more pronounced vertical projection. It is possible that the smaller faults and fractures do not reach the crystalline basement.

The faults are presumably of low average vertical projection, although projections of more than 100 meters have been found in several wells.

Fracturing of the system may be attributed to one or more of the following causes: (a) the considerable movement of the intrusives and extrusives throughout the system; (b) dislocation through tension of the beds surrounding the magma and laccolithic intrusive bodies; and (c) the expansion and subsequent contraction of the igneous intrusives.

As shown by the various known petroliferous fields, the two structural characteristics of the system are favorable to the accumulation of gas and oil. However, it is obvious that if there were oil round the intrusive bodies, or underneath their ramifications, such oil would inevitably produce surface seepages as the result of movement of the oil along the intrusives.

Since, in a belt more than 1,500 kilometers in length, containing innumerable intrusives covered by sediments or exposed and deeply eroded, no active oil or gas seeps are known, we must assume, either that the system does not contain any appreciable quantities of gas or oil, or that such occurrences are not associated with structures of this type. The last hypothesis is untenable, since it seems to be contrary to all the known laws of structural accumulations of petroleum.

Again, if petroleum existed in the system and was not related to the structures formed by the intrusives, it must be related to the faults. As in the first case, the oil must inevitably have produced active seeps, considering the huge area of the sedimentary belt, its deep peneplanation and erosion, and its diaclastic nature. It is hardly possible to admit the existence of any considerable quantities of oil and gas in faults or fissures without signs of active seeps. This contention is reinforced when we consider the shallowness of the beds covering the Iraty, which is the only horizon with characteristics favorable to the generation of hydrocarbons. All the known occurrences of exploitable petroleum in similar tectonic conditions have been found in association with active seepage. For instance, in the oil-bearing area of Tampico, in Mexico, in conditions very similar to those of Southern Brazil, although in Cretaceous and Tertiary rocks,

there are hundreds of active oil seeps indicating the presence of accumulated petroleum and gas.

From what has been stated, it should be concluded that the system apparently does not contain large quantities of oil and gas, or source rocks capable of producing such quantities, since obviously such occurrences would have appeared in some of the faults or fissures in an area of Gondwana rocks as large as that occupied by the Paraná Basin in Southern Brazil, or Paraguay, Eastern Argentina, and Uruguay.

General Conclusions

1. Exploitable petroleum is not known to originate in the Gondwana rocks of the Southern Hemisphere, India, or South America.

2. Despite the relatively favorable structural conditions for accumulation of petroleum, and although traces of oil and gas are known, the Gondwana rocks of Southern Brazil do not show stratigraphically favorable conditions for occurrences of oil in exploitable quantities.

3. The bituminous shales of the Iraty form the only petroliferous horizon of the Santa Catharina system.

The traces of oil found above and below the Iraty horizon are apparently derived from that horizon.

The bituminous shales of Iraty represent a valuable latent reserve of oil that could be worked by the usual process, provided economic conditions were favorable.

4. Geological prospecting for oil-bearing structures should be directed to the areas of developed Tertiary, Cretaceous, or possibly Devonian sediments such as those of the geologically little explored Brazilian territories on the borders of Bolivia and Perú.

Intensive wildcat borings should be made after this area has been stratigraphically and structurally studied.

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APPENDIX

GEOLOGICAL MAP OF SOUTHERN BRAZIL

GONDWANA SEDIMENTS AND TRAPS BETWEEN LATS. 16° AND 33° S. AND 45° AND 58° LONG. W. GR.

This is the most complete map of Southern Brazil so far compiled, and embraces the occurrences of Gondwana rocks in the states of Minas Geraes, São Paulo, Paraná, Santa Catharina, Rio Grande do Sul, parts of the states of Matto Grosso and Goyaz, the Republic of Uruguay, and the zones bordering Argentina and Paraguay.

As indicated in the sub-title, there are represented only the Gondwana rocks, with particular reference to the Permian and Triassic sedimentary belt, and the escarpment of the Serra Geral, whose western limit crosses the states of São Paulo, Paraná, Santa Catharina, and Rio Grande do Sul, and whose southern limit ends in Paraguay.

The following were the chief sources of information used in drawing the map.

"Croquis" and unedited maps of the states of São Paulo, Paraná, Santa Catharina, and Rio Grande do Sul from the Serviço Geologico, made available by the kindness of the director, Dr. Euzebio de Oliveira, and Dr. Avelino Ignacio de Oliveira

Geological map of the State of Minas Geraes by Dr. Djalma Guimarães and Octavio Barbosa (1934, unpublished)

Geological map of the State of São Paulo, by the Geographic and Geological Commission of that State (1929)

Map of the State of Paraná, by Dr. E. de Oliveira (1925)

For the State of Goyaz, material was taken from the paper by Dr. Glycon de Paiva Teixeira, *Bulletin 32* (1932)

For the State of Matto Grosso, from the paper of C. L. Baker (1923)

Data for the Republic of Uruguay were based on information furnished personally by Dr. E. Terra Arocena, director of the Instituto de Geologia y Perforaciones del Uruguay, and on the detailed maps of J. Falconer, K. Walther, J. G. McMillan and D. Rey Vercesi (made between 1930 and 1933)

For Argentina and Paraguay, from the paper of Anselm Windhausen (1932) and C. L. Baker (1923)

In addition, full consideration was given to the bibliographic material referred to in Part I.

The information obtained from the sources mentioned was supplemented, and in some cases radically modified, by the writer, who made numerous field observations and exploratory trips in all the areas mentioned.

The belt of pre-Gondwana (Cretaceous and Tertiary) sedimentary rocks lying discordantly on the traps at the west represents thin sandstone beds of sporadic occurrence. This belt is indicated on the map by broken horizontal lines without definite limits.

The same sedimentary rocks in São Paulo (Baurú sandstones) and Matto Grosso probably extend into Paraguay, and they occur in greater thicknesses in southwestern Uruguay (Paso Ulestie) and in Eastern Argentina.

The western limit of the trap is assumed: up to the present it has not been properly surveyed, and the trap may extend farther in this direction than is known. The limit shown on the map has been traced chiefly by the known outcrops and well cores observed.

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VOL. 19, NO. 12 (DECEMBER, 1935), PP. 1806-1818, 2 FIGS.

NEW THEORY OF CONTINENTAL SPREADING[1]

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ABSTRACT

The thesis may be considered a corollary of Gutenberg's theory of continental spreading. The paper should be read in conjunction with those by Gutenberg.

Few assumptions are required if it be granted that our distinctions between solid and liquid are artificial and expedient rather than actual and that what we term solids may flow with a time factor which is great and may approach infinity. It must be assumed also that the original crust of the earth was of sima and that the lighter sial was formed from it.

A compromise is effected between the concepts of permanence of continental masses and of instability and movement relative to one another. For the causes which produce the elevations and depressions on the original sial sheets are such as might permanently affect such parts of the sheets. Thus both original land areas and water-filled depressions would be persistent though they would tend to increase in area with the spreading of the sheets. Changes of form would take place as isostatic conditions became affected locally both by added loads of light sediments deposited by the ordinary agencies and by the thinning of the sheets in other places by erosion. The land bridges between continents required by Schuchert and Bailey Willis are easier to account for if we regard the continental masses as being closer together when these bridges existed and the consequent foundering of such bridges would necessarily follow upon the stretching of the sial sheets as the masses drew farther apart. Again, some of the land bridges may have been due to the local junctioning of irregular-shaped sial sheets moving in opposite directions from the polar regions.

INTRODUCTION

A recent paper by the writer (1)[3] dealt with the distribution of oil fields from the point of view of Gutenberg's theory of continental spreading (2, 3). So far as petroleum was concerned, an endeavor was made to base the thesis on such fundamental ideas as arise from Trask's work on source sediments (4), but in dealing with the spreading of the continental masses the ideas put forward by Gutenberg were closely followed. Further consideration has led to the conclusion that a simpler theory of continent building and distribution may be obtained by sticking to first principles throughout.

Many petroleum geologists believe that the time has come for closer study of the world as a whole. The symposium on continental drift arranged by The American Association of Petroleum Geologists (5) is evidence of it and in his opening paper van der Gracht made

[1] Manuscript received, April 23, 1935.

[2] Freney Kimberley Oil Company, 7–12 Third Floor, Warwick House, St. George's Terrace.

[3] Numbers in parentheses refer to Bibliography at end of article.

a very powerful plea for such broader studies in connection with the geology of petroleum. The contributions both of idea and of evidence evoked by the symposium brought about advances in geological thought which may be of more importance than the theory discussed. American geologists, who have tended to believe in the permanence of continental masses in more or less their present positions but with, of course, some modifications of shape and area are inclined to modify their views somewhat in recent years. Papers by Schuchert (6) and Bailey Willis (7) develop the theory of land bridges without requiring the movement of the main continental masses, though it would appear from their paleogeographical reconstructions that the crustal movements required by them, while not so profound as the movements required by those whose views they wish to controvert, are, nevertheless, of considerable dimensions.

NEW THEORY OF CONTINENTAL SPREADING

Critical consideration of Gutenberg's papers has led the writer to formulate a tentative hypothesis of his own. It is frankly based on Gutenberg's ideas, but has been thought out in order to meet some of the more obvious objections which have been advanced against his concepts. Moreover, the writer thinks that his new theory is more in accordance with observed phenomena and involves fewer of those difficulties which are only obviated by making assumptions which are entirely theoretical and unsupported by evidence. For example, the writer is able to dispense with the idea of the separation of the moon from the earth and that the former owes its origin to the carrying away of the greater part of an original cover of sial. Again, Gutenberg is not quite happy concerning the great Mediterranean zone of weakness formerly occupied by the sea known to paleogeographers as the Tethys. He accounts for this as an original tear in the sial sheet probably formed at the time of the moon's separation from the earth. Such an hypothesis is entirely incapable of proof and may be considered as highly improbable. We shall find later that this may be accounted for in a simple and reasonable manner without postulating a tear.

Let us go back to fundamentals. Many geologists will agree that it is probable that the original crust of the earth was closely akin to the sima and that the sial has been formed from it by oxidation, hydration, erosion, re-sorting and re-deposition as sediments. This original crust of sima was entirely or almost entirely covered by water. There must have been a greater volume of free water at that period, for immense quantities of water are not only locked up in the

sedimentary deposits, but have also been abstracted from the original volume by the hydration of minerals and the chemical processes involved in the development of the lighter sial. Other large quantities have gone into the formation of living things, plant and animal. Under such conditions more equable temperatures would prevail over the whole of the globe and the existence of ice cappings at the poles may be doubted. Astronomical researches have established the fact that the speed at which the earth is revolving on its axis is gradually slowing down and must have been much greater at a period as far back as the one we are considering. Again it is thought that the moon was nearer to the earth in past geological times and, in consequence, the gravitational, tide-forming pull was much greater. Under such conditions the sheet of water covering the crust would tend to pile up at the equator and would tend to leave bare land tracts at both poles. The agencies at work which would effect oxidation, hydration, erosion, and sedimentation, in these two polar tracts must have been very intense and sheets of sial would be rapidly formed on both. As soon as these sial sheets became thick enough and sufficiently consolidated to upset the hydrostatic equilibrium at the poles, both sheets would begin to move and the problem resolves itself into one concerning two fluids—a lighter one resting on one more dense. The forces acting upon the sheets of sial would be

a—gravity

b—such as arise from the rotation of the earth.

Gutenberg discusses the effects of such forces acting on a single sial sheet at some length. By considering the effects on two such sheets, one in each of the polar regions, we avoid any supposition concerning the moon altogether. It is improbable that these sheets would be either equal in size or similar in configuration. They would tend to move towards each other in the direction of the equator and would be affected by forces causing a westerly drift as well as a tendency to flow radially in every direction from a center. The equatorial zone of weakness and especially that part of it formerly occupied by the Tethys now assumes a new significance. Instead of having to explain it as a tear formed in some way or other in an original block of sial, it merely becomes the zone along which the two sial sheets, advancing from opposite poles, came together. Irregularities in the configuration of the sheets make it certain that only comparatively small areas would meet at the first points of approach. Geological ages might elapse before contact became approximately general. It is also possible and even probable that there would be reactionary movements after the first onset of contacts and that gaps between the sheets

would re-open to a greater or less extent. Thus we can explain the formation and subsequent foundering of land bridges and isthmian links. If there be any truth in this thesis, this flowing of the sial is still in progress. Gutenberg brings forward a good deal of evidence to show that the floor of the Pacific Ocean is of sima with practically no covering of sial. The sial sheets have not yet flowed over this area. They may be doing so. Possibly the area of these tracts of sima as yet uncovered by sial may give us another line of attack in estimating the age of the earth.

The various anomalies and curving changes in direction shown in diagrammatic representations of the equatorial geosynclinal belt are those we should expect from a consideration of Gutenberg's principles in so far as the southern sial sheet is concerned. Africa, Arabia, and India, representing the central parts of the southern sial sheet, have pushed farther north than have Australia and South America on the margins and part of the sial sheet still remains as a considerable development around the South Pole. The northern mass seems, on the whole, to have moved more slowly, though it has drawn away from the North Polar area, which is, in this case, an ocean tract. Differences in size, thickness, or composition of the sheets, as well as irregularities in original form, would account for many such anomalies. At any rate the great masses represented by North America and Asia have pushed farther south than has Europe. The Asiatic mass has transgressed well south of the Equator, blocking the northward progress of the Australian mass, which appears to have moved northeast as though sliding around to escape the pressure of the great south-moving Asiatic block. In this way the outward curve toward the east into the Pacific of the sial margin on which New Zealand is situated has been formed.

If we examine the major Mesozoic geosynclines we find that they completely encircle the Pacific. This is again in accordance with our theory. Much has been written concerning the equatorial geosynclinal belt, but the explanations advanced to account for it are as entirely hypothetical as those now put forward. If we may regard it as the zone of contact between two sial sheets originally independent of one another, it is easily explained. The general arrangment of these geosynclinal areas, the westerly re-entrant between the Australian and Asiatic masses and the easterly re-entrant in the central American region are suggestive of such an explanation. Bailey Willis, in his discussion of Wegener's theory, states that

It is well known that these two continents (North and South America) were long separated and have only recently, geologically speaking, been united (5).

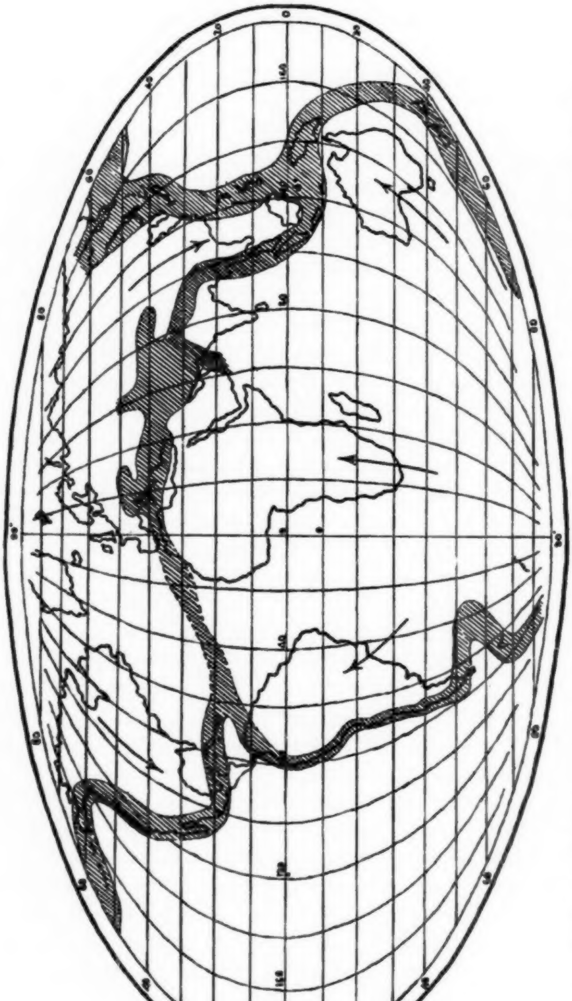

FIG. 1.—The two sial sheets showing boundaries formed by major Mesozoic geosynclines. Arrows indicate directions of flow suggested by writer.

We also know that a greater Mediterranean Sea separated Africa from Europe in comparatively recent time. It is accepted that the southern part of the Indian Peninsula has only recently, again geologically speaking, become part of Asia and has paleontological relationships with both Africa and Australia.

Thus all the major geosynclines affecting the earth's crust fall into line as being similarly formed and there is no need for abstract speculations concerning them. The equatorial geosynclinal areas are marginal just as are the others, but are formed of the margins of two individual sheets moving toward each other in opposite directions.

One important corollary to the theory has not been dealt with and can only be put forward here as a suggestion to other workers in this field. If the sial sheets were unequal in mass and distribution, tensional forces would be set up in the rotating body which would result in sheering. The writer thinks it is possible to work out the directions which such sheer planes would take, but not in a brief paper. It should be possible to test the validity of the theory by a study on these lines and a comparison between the theoretical sheer planes and those which are known to exist in the earth's crust. They would account for certain anomalies in continental structures and distribution.

EVIDENCE IN AUSTRALIAN AREA

The full effect of these conflicting forces in the Australian region would be felt in the Island of New Guinea and in the northern parts of the Australian continent. David, Brouwer, and others (8 and 9) are of the opinion that New Guinea is being forced and folded against the Australian block by pressure from the north. Nouys, Wegener, and van der Gracht believe that the New Guinea mass is moving away from Australia in a northerly direction (5). These apparently conflicting views may not be so irreconcilable in a relative sense as would appear. Structural lines observed in New Guinea and neighboring islands suggest, as the writer has already shown (10), that this mass is being squeezed against an Australian horst. These structural lines are broken and curved back opposite to both eastern and western edges of the Australian block. The main structural lines evident in New Guinea form a curve extending from west to east and southeast which is parallel with the central axis of the island and is concave toward Australia. Most writers on this subject overlook the fact that in the southern part of New Guinea (Papua), Australian trends still persist, especially in the coastal regions near the Purari and Vailala rivers. Here beds of Miocene age are steeply folded on axes which extend almost north and south, or almost at right angles to

the main structural trend of the island. Reefs extending out to sea near Orokolo and Kerema also have this north and south trend. Strata of the same age take up the normal New Guinea trend a few miles inland. In the Ie Hills near Kerema there exists a most interesting unconformity in Tertiary sediments. Miocene clays and grits, folded on north and south axes, are overlain by clays, sands, and limestones of Pliocene age which lie transversely across them with an east-west orientation and southerly dips (11, p. 17). Thus in this part of the island, uplift along the east-west axis has been very recent and suggests the encroachment of the east-west system of folding toward the south over structural lines coming directly from the Australian area.

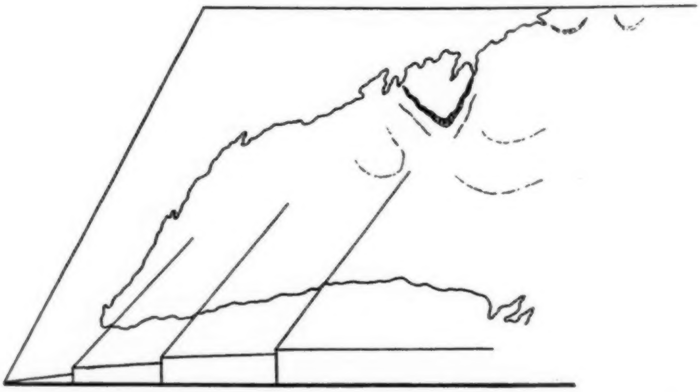

FIG. 2.—Structural diagram of western part of Australian continent showing fracture blocks on north, step faulting on west, and main structural lines in central area.

The structure of the northern parts of the Australian continent possesses features of great interest from the writer's point of view. Pre-Cambrian and Archean masses form three festoon-like arcs along the northern margin from the Kimberley region of Western Australia to the Gulf of Carpentaria (13, geological map and pp. 37–38). These are formed by three Archean blocks which are broken from the main continental platform and tilted toward the north like the fractured margins of an ice-floe. The Kimberley area is the largest of the three fractured blocks, which become smaller and less pronounced in the more easterly areas. These phenomena indicate great pressure from the north upon the continental platform of Australia. The movement seems to have reached a maximum at a later date than the Cambrian and earlier than the Devonian period, which is represented by fringing

coral reefs around the margins of the Kimberley mass. There is evidence, however, which indicates that the movement had already begun in pre-Cambrian times and has continued, in greater or less degree, to comparatively recent time. The rest of the Archean platform of Western Australia was downwarped toward the west at a later period and is marked by north and south trending folds and faults which have a general tendency to throw down the platform toward the west. This movement is either late Permian or Triassic in age and is probably connected with the diastrophism associated with the foundering of Gondwanaland. As already stated, there is evidence indicating that the forces resulting in east-west structures continued, with greater or less intensity, at least until the Jurassic, for north-south folds and faults in the Permian strata are affected and displaced by cross-folding and faulting with east and west trends.

Most of the east-west folding in Western Australia has been caused by pressures coming from the north and it may be that the structural trends previously described, in the New Guinea area, have been caused by resistance to a northerly migrating Australian block which would account for them equally well. In this case New Guinea would be merely a ruck in front of the moving mass, for Australia is, of course, part of the north-moving sial sheet. The apparent southerly movement of the New Guinea area may be relative only to the Australian block. The whole may be moving north and the apparently conflicting views quoted at the beginning of this section are due to observations of different phases in a problem of relativity.

Thus there seems to be a good deal of evidence in the Australian area in support of this thesis, in fact, the writer was impelled toward reasoning on such lines by his own observations on the islands of Timor and New Guinea, as well as in northern Australia.

CONCLUSIONS

The thesis, which the writer feels he may have inadequately presented, is based on a study of Gutenberg's theory of continental spreading and may be considered as a corollary to that theory. The present paper should really be read in conjunction with those of Gutenberg. Some of the main points and implications are summarized in the following paragraphs.

Few assumptions are required if it be granted that our distinctions between solid and liquid are artificial and expedient rather than actual and that what we term solids may flow with a time factor which is great and may approach infinity. It must be assumed also that the original crust of the earth was of sima and that the lighter sial was formed from it.

A compromise is effected between the concepts of permanence of continental masses and of instability and movement relative to one another. For the causes which produce the elevations and depressions on the original sial sheets are such as might permanently affect such parts of the sheets. Thus both original land areas and water-filled depressions would be persistent, though they would tend to increase in area with the spreading of the sheets. Changes of form would take place as isostatic conditions became affected locally both by added loads of light sediments deposited by the ordinary agencies and by the thinning of the sheets in other places by erosion. The land bridges between continents required by Schuchert and Bailey Willis are easier to account for if we regard the continental masses as being closer together when these bridges existed and the consequent foundering of such bridges would necessarily follow on the stretching of the sial sheets as the masses drew farther apart. Again, some of the land bridges may have been due to the local junctioning of irregular-shaped sial sheets moving in opposite directions from the polar regions.

Climatic conditions which geologists find to have existed in different ages are accounted for. For example, in the Gondwanaland areas southern India has moved northward across the equator with greater relative speed than has Australia, which has been forced eastward by a south-moving Asiatic mass. In this way the connection has been broken. Something of the same kind has occurred relatively to the southern part of Africa. In any case the effects of land bridges and the confining and opening out of seas have been shown to have marked effects upon climatic conditions.

Problems connected with the distribution of faunas in past geological ages become less difficult if such movements as are suggested actually took place.

The problem of the major geosynclines is simplified in that all geosynclines are considered as being of the same nature. They are all similarly formed and are all marginal areas of the sial sheets. The equatorial geosynclinal belt extending from Central America and the West Indies through the Mediterranean, Caucasus, Himalayas, Burma, East Indies, and New Guinea is formed by the coming together of two sial sheets advancing north and south from the poles. It is the common marginal zone of both sheets which have merged along this zone. Even opponents of such theories admit that North and South American land masses have only recently become joined; that a wider and more extensive Mediterranean Sea formerly separated Africa from Europe; that southern India has only recently become part of the mainland of Asia.

A great land area existed west of the British Isles in early Paleozoic time. Why not the North American continent? If the continents are permanent and fixed what other land mass could it have been? Something must have moved.

The theory affords a good and simple explanation for anomalous changes in direction which occur in the geosynclinal belt. It does not necessitate any great changes in the axis of rotation of the earth and the consequent moving of the poles, nor is it concerned with such problems as the separation of the moon from the earth.

In the Australian region it accounts for structural features which exist in New Guinea and in the northern parts of Australia.

On the other hand, the main objections to the theory would appear to be that at present it can not be demonstrated that the original crust of the earth was of sima, though there is evidence which points in this direction. There is also little direct proof of the movements of land masses. The evidence is purely circumstantial. Such movements do seem to have taken place in such areas as the East Indies, New Guinea, Japan, New Zealand, and South America among others. Other objections will occur to geologists who read the paper critically and especially from local points of view, for it is impossible to trace every implication of such an hypothesis through every circumstance which may be affected by it, nor does the writer think it possible to formulate any theory which will meet every objection to it. This paper, written in the field, is intended to be suggestive only. The study and the library are necessary for anything beyond this. It may be amended, clothed with more substance, or controverted, but if it provokes discussion and brings forth new ideas it will have fulfilled its purpose.

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DISCUSSION

W. A. J. M. VAN WATERSCHOOT VAN DER GRACHT, Heerlen, Holland (discussion received August 31, 1935): Gutenberg's hypothesis of continental spreading is worthy of notice, since it contains several points differing from Wegener's hypothesis, which eliminate to a certain extent difficulties, and which bring forward new lines of possibly fruitful thought. It has, in my opinion, one great drawback, namely that it brings into play the hypothetical birth of the moon out of the earth. I am very glad that Dr. Wade does away with this item.

Cosmologic obstetricians should leave the moon in peace. I do not at all believe it to be a daughter of the earth, but only a diminutive sister, equally a child of the sun as her many large and small planetary brothers and sisters. However, any possible separation from the earth would only be thinkable in the gaseous stellar phase of the latter, and for such a relatively small body as the earth, this phase could only have been very short-lived, speaking in astronomical terms of time.[4] At this phase there could not yet have been any question of either sima or sial.

There has been a lot of humbug about this supposed birth of the moon out of our earth; some would place it in post-Archean time, some as late as in the Permian, and I have even seen it placed in the Pliocene!

In his paper in the *Proceedings* of the World Petroleum Congress of 1933 (Vol. I, pp. 73–77), Wade very lucidly summarizes Gutenberg's hypothesis. It chiefly comes to this, that the Pacific Ocean is seen as the only primeval ocean, with a floor of sima, while all the rest of the earth's surface consists of a massed sial floe, partly covered by water, and floating in the sima. This floe is thickest within the continental nuclei, thinner elsewhere, most attenuated under the other "oceans," notably the Atlantic. The boundaries of the primeval Pacific region are marked by more or less *vertical* dividing planes between this ocean and the adjoining continental areas, as proved by the behavior of seismic waves. This feature is absent for all other "oceans."

Neither Wegener nor Gutenberg was concerned as to where the sial came from. Gutenberg believes that the sial mantle was originally continuous all over the earth, but that daughter Moon, leaving home, took most of it with her, and left her mother sorely despoiled. The latter then proceeded to spread out over herself what was left of her originally perfectly good clothes as well as she might. They got distressingly thin and torn in places during the process, and even then she did not yet reach the Pacific area.

Wade eliminates this sad domestic episode and for this we may be grate-

[4] The mass of the earth is only 1/333,432 of that of the sun; the moon's only 1/27,000,000. Jeffreys, from condition of present orbit, calculated the birth of the moon roughly at 4,000,000,000 years ago, while the age of the earth's crust can be placed at ± 2,000,000,000 years ago (Rutherford).

ful. He devises another plot. Mother Earth was born, as all of us, bare, and she only gradually fabricated her sial mantle, starting from both poles, and gradually extending and stretching it toward her rotund equatorial waistline. She more or less succeeded so far, except again for the Pacific region. She had no daughter Moon.

Getting back, however, to more conventional scientific language, I think that Wade's idea is decidedly worth further thought. I am not quite prepared to adhere in all respects to the idea that the sial has only formed from sima "by oxidation, hydration, erosion, re-sorting and re-deposition as sediments," and then preferably at the poles, because a higher speed of terrestrial rotation and a smaller distance of the moon, would tend to bare the poles of the originally continuous watery outer mantle. I believe that sial formed, and is still so forming, notably under the more massive continental areas, by segregation and re-grouping of the lighter sima particles, and that it is the consequent local thickening of the sial crust from below, that causes certain continental nuclei, larger and smaller, to show a continuous tendency to rise, regardless of denudation through practically all historic geology. Isostatically this is only conceivable if the sial crust nevertheless thickens, either by material being added by subcrustal magmatic currents or by segregation of sial.

It is very true that sial floes, spreading from the polar regions to the equator, and meeting along an irregular equatorial belt, certain nuclear masses travelling considerably in advance of others, would explain a considerable part of the rather baffling orogeny along a more or less equatorial greater circle of the globe. It does not so well explain the location of the Permo-Carboniferous orogenic belt as the Alpine diastrophism, and we must bear in mind that the first was evidently of greater magnitude than the second. The circum-Pacific Andean (at large) belt is of course something totally different, but here a certain difficulty arises when we have to explain the outer, older "borderlands" on the outer edge of the Cordillera of North and South America. The creation of the minor oceans is not troublesome; they would be stretched out, thinned, sial floes, caused by differential drift of the continental nuclei, which were originally land-connected. However, the western Pacific Ocean, within the region studded with the South Sea Islands garlands, has more Atlantic character than truly Pacific; *whence the sial?*

The difference between the poles of the Variscan and the Alpine orogenic belts, not to mention the older orogenic revolutions, suggests a variable location of the poles of the earth. This may be only relative, as to the outer crust only, and not as to the major interior masses.

It would be most interesting to probe Wade's hypothesis further as to sedimentary and structural detail, as he attempts to do for the Australian region, which is comparatively less known in detail than North America and western Eurasia. Recent gravitational work in the oceanic regions by Vening Meinesz, and notably his striking belt of negative anomaly through the entire Sunda Archipelago, one of the areas of evident present-day orogenic activity, should thoroughly be taken into account, as well as the geological deductions of Umbgrove for this same region.

As I have said already, when presenting my own contributions on the theory of continental drift (which naturally, after 1928, will have to be changed in many details!), all this is by no means devoid of interest to the petroleum

geologist, who faces more worldwide problems of pioneering. Dr. Wade's work and thoughts prove this, although I may personally not be in full agreement with his conclusions, laid down in his aforementioned paper read before the World Petroleum Congress, to the effect that North America, and possibly eastern Asia, would have enjoyed more favorable conditions during Paleozoic time for the formation of source rocks of petroleum, than western Eurasia or other parts of the world. I am quite convinced that, equally as the forelands of the Alpine chains, the forelands of the Permo-Carboniferous chains must contain oil deposits in many other regions than in North America (and the Ural Mountains), and that it is merely the fact that the European Variscan foreland is deeply buried under Mesozoic-Tertiary sediments, which accounts for the apparent lack of such oil pools. I firmly believe that modern drilling technique to great depths will soon efface this incongruity.

Arthur Wade (reply to discussion received, December 6, 1935):—The writer has suggested in his paper that discussions on such subjects are often more valuable than the paper itself. He is especially glad that Dr. van der Gracht finds points with which he disagrees and that he gives reasons and alternative views. It is to be hoped that other geologists will do the same. Theses like those of Wegener, Gutenberg, and the present writer are simple and elementary attempts to solve a complicated problem. We look at the present configuration and distribution of the land and water areas on the globe and we can picture pretty well what has happened since Mesozoic time. Earlier than this the pictures become more and more blurred and indistinct with blank places here and there. It is quite certain for example that current ideas with regard to orogeny and the distribution of land and water in the Australian area in Permo-Carboniferous time must be profoundly modified in the near future. All we are doing at present is in the direction of providing material for future workers. This is why discussions are so valuable since they tend to collect a wider range both of information and of ideas.

The writer, after careful consideration of Dr. van der Gracht's views with regard to the origin of the sial, finds he can agree with him without seriously modifying the views set forth in the paper. Thickening of the sial from below may take place, and would be accelerated, he thinks, by movements and stresses at the zone of junction between sial and sima.

With regard to the Atlantic nature of the western Pacific, the author has long been inclined to think that the sial sheet spread into this area at some early date and has been drawn back in a westerly direction along a belt which is almost equatorial. The configuration of the land masses and the structural lines such as we definitely know suggest this.

The paper prepared for the World Petroleum Congress was written deliberately for the purpose of stimulating discussion and perhaps controversy. The writer took Gutenberg's theory and endeavored, not very successfully perhaps, to account for the distribution of the oil-field areas on the earth's surface on this basis. Since he never entirely accepted Gutenberg's hypothesis he has never entirely accepted his own conclusions derived from that hypothesis. Dr. van der Gracht's concluding paragraph is of particular interest and importance. Such an optimistic view from such a source should provide a great stimulus to many petroleum geologists at the present time.

4

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 19, NO. 12 (DECEMBER, 1935), PP. 1819–1825, 2 FIGS.

GEOLOGICAL NOTES

GEOLOGY OF CALIFORNIA: SOME CORRECTIONS

Aside from some typographical errors, the *Geology of California*[1] contains several passages that the writer no longer believes, and others that for one reason or another seem to have been misinterpreted by some readers. A brief discussion of a few of these passages may assist in preventing the harm that they might otherwise do.

1. The statement that several earlier writers had exaggerated the importance of faulting in the structural evolution of the Coast Ranges has by some readers been interpreted to mean that very few faults occur, and that all of them are definitely known to be of late Tertiary or Pleistocene origin. This interpretation is incorrect. Many faults occur in the Coast Ranges, and several of them are long and of vast displacement. For a few of them there is excellent evidence of Middle Tertiary movement, and for two or three there is a suggestion of recurrent movement. It is even possible, as the present writer suggested in 1925 and again in the *Geology of California*, that in the granitic districts of California, such as Salinia (not "Salina") and Mohavia, recurrent faulting may have dominated structural evolution throughout post-Jurassic time. Some details concerning one such possibility will be published at an early date.

2. With reference to unconformities, some of the statements in the *Geology of California* seem also to have been misleading, and some do not reflect the author's present belief. As a protest against the accepting of unconformities on weak, indirect evidence, it was pointed out that many unconformities had been moved; that some of those now accepted may turn out to be merely minor discontinuities; and that the importance of an unconformity should not, in general, be decided until its stratigraphic and structural aspects are known from detailed paleontologic work and areal mapping. It was also stated that some of the discordant contacts of the Coast Ranges occur between formations not very near one another in the geologic column. The folding that produced them is thus not closely dated, and may have occupied a great or a small part of the time not represented by sedimentary rocks in the sections where the discordances occur. In all of this there was no intention of denying the existence of unconformities, or of implying that a study of them is not important for an

[1] Ralph D. Reed, *Geology of California* (Amer. Assoc. Petrol. Geol., 1933), 355 pp.

understanding of structural evolution. This fact should have been obvious from the emphasis that was given to recurrent folding as the dominant feature of Coast Range structural evolution.

On the relative importance of the Tertiary and Pleistocene folding episodes, the opinion was expressed that the latter is the result of a more violent and general disturbance than were any of the earlier ones. In the light of work done since the volume was written, this opinion needs modification. It now seems possible, though not certain, that the difference may be due largely to the fact that the folds developed during the earlier disturbances were broader than the Pleistocene folds, but not necessarily less important otherwise. In the San Rafael Mountains, for example, recent studies have brought to light the fact that a post-Cretaceous folding episode raised an anticlinal area and permitted the erosion from it, before Middle Eocene time, of probably 10,000 feet of Cretaceous rocks. In spite of the fact that differences in dip between Cretaceous and Eocene rocks are not very great in the area, this folding was nevertheless important.

In another respect the ideas expressed about unconformities in the *Geology of California* may have been even more misleading. Although exceptions were recognized, the point was made that most of the known strong angular discordances occur between formations that are elsewhere separated by at least a whole formation. This fact was assumed to mean that the folding that produced the unconformities continued during a long time. Further work suggests, however, that the cases formerly considered exceptional may prove to be the more instructive as to the time occupied by a folding episode and that most of them, perhaps all the more important ones, were short-lived. This matter will be discussed in more detail in a forthcoming publication.

3. The *Geology of California* used a classification of the Miocene that now seems inadequate. On the basis of paleontological views current at that time, a twofold classification into Lower and Upper Miocene was adopted. That this classification did not fit the physical history perfectly was recognized, however, as may be seen from the following passage (p. 206).

> Local angular unconformities occur at different horizons in the Temblor-Monterey section . . . and there is a possibility that some of them may be found to separate the two formations in a few localities. Some are certainly below the formation boundary, however, and others are certainly above it.

Additional study shows that the more important unconformable contacts are all either above or below the boundary as it was drawn at the time, and additional paleontologic study has also shown that

the paleontologic "break" between the "Lower" and "Upper" Miocene is less pronounced than it was formerly asserted to be. The present tendency is therefore to separate the "Button bed" and "Gould shale" from the top of the older Lower Miocene, and the *Valvulineria californica* zone from the base of the Upper Miocene, and to unite the two as the Middle Miocene.

TABLE I

PRESENT CLASSIFICATION OF MIOCENE STRATA

Upper Miocene.	Coarse white sandstone, diatomite, et cetera, including old Santa Margarita and much of the Monterey.
	Local unconformities in several districts
Middle Miocene.	Largely siltstone, including part of old Monterey, Temblor, Maricopa, and other formations.
	Local unconformities, faults, many volcanic flows
Lower Miocene.	Sandstone and shale. Much of Temblor and all of Vaqueros

4. Another passage that misled some readers related to the structure of the Coalinga district. Figure 10-A and B, on page 53, seems to have been especially misleading. Figure 10-A was redrawn from a section made for another purpose several years previously, and the slight amount of revision given to it was not in all respects happy. The section is erroneous, for example, with respect to the labeling of "White Creek syncline," which is obviously not where the arrow points, but farther east. The figure is also misleading in that it fails to suggest that the Temblor and Santa Margarita formations are probably overlapped by the Pliocene west of the Waltham Canyon fault just as they are in Alcalde Hills and elsewhere. It is true that the Temblor reaches the line of the fault in one place, but along the line of the section there is no reason to believe that it does so. A few miles farther southeast the Pliocene lies with angular discordance on the Cretaceous, although across the Waltham syncline a mile or two west it lies on the Santa Margarita. Since this condition is probable along the line of the section, the figure should at least have been drawn so as to suggest this probability.

In Figure 10-B, the present position of the San Andreas fault is indicated by a dashed line and by the caption "San Andreas line," instead of the solid line and the words "San Andreas fault" of Figure 10-A. Referring to this section, B. L. Clark[2] writes:

> Judging from his sections, Reed admits the old age of the San Andreas fault zone.

A few pages earlier, however (p. 38), referring to the San Andreas fault, Reed had written:

[2] B. L. Clark, "Tectonics of the Mount Diablo and Coalinga Areas, Middle Coast Ranges of California," *Bull. Geol. Soc. America*, Vol. 46 (1935), p. 1054.

> To some it is an ancient feature. . . . To others it is a recent feature. . . . At present there is, on the whole, little more reason for holding one of these views than the other.

Figure 10-B was drawn and labeled with this condition in mind, but all efforts were apparently vain, and Professor Clark was unfortunately misled.

Instead of trying to re-draw this diagram in such a way as to make its interpretation unmistakably clear, it may be better to

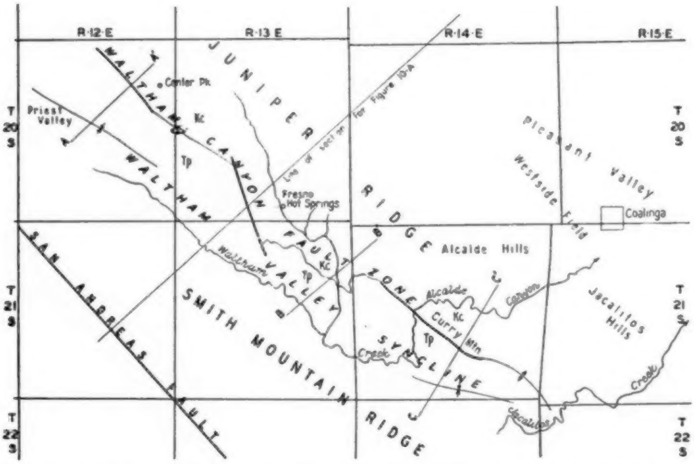

FIG. 1.—Sketch map of Waltham Valley region. Townships are approximately 6 miles square. For additional geological details, see report by Pack and English, cited in text.

subjoin a few notes and simple sketches to illustrate the conditions that now exist along the Waltham Canyon fault zone and that must be kept in mind in trying to decide among possible interpretations of its structural history.

The Waltham Valley region was mapped in 1913 by R. W. Pack and W. A. English, whose report, with black-and-white geological map,[3] was published in 1914.

The writer's acquaintance with the region began in 1923, and has been gradually extended and improved by longer or shorter visits during nearly every year since that time. During 1934, in particular, he examined two critical areas along the fault zone, and had his observations and interpretations checked by two men widely experienced

[3] "Geology and Oil Prospects in Waltham, Priest, Bitterwater, and Peachtree Valleys, California, with Notes on Coal," *U. S. Geol. Survey Bull. 581-D* (1914).

in Coast Range geology and thoroughly familiar with the formations of the Coalinga district. The conclusions are, briefly, that the mapping of Pack and English in the vicinity of the Waltham Canyon fault zone is substantially correct; that their interpretation of this "fault" as essentially a fold[4] is also correct; that the "old line of weakness," the existence of which they infer, is the unconformable contact between

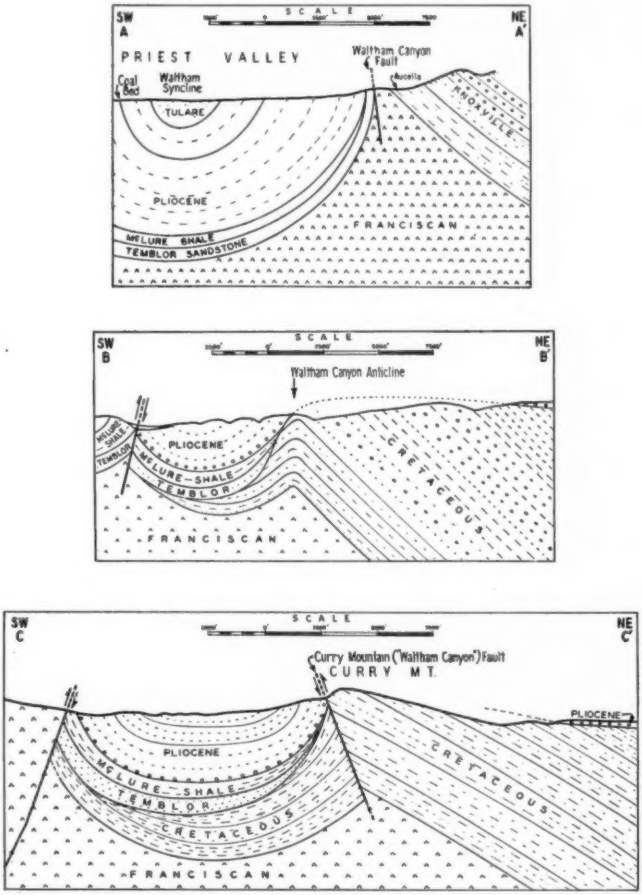

FIG. 2.—Structure sections across Waltham Canyon fault zone. For location of sections see Figure 1.

[4] *Ibid.*, p. 137.

weak Franciscan and strong Cretaceous rocks; but that their surmise of possible old faulting along this line of weakness, though not entirely impossible, has no shred of tangible evidence in its favor.

Professor Clark's investigation, made during the same time as the writer's, has led to radically different conclusions, as all readers of his well known structural papers no doubt realize.

In order to illustrate the conditions observed and inferred by the writer to exist along this fold, and thus perhaps to help explain in what sense Figure 10-A and B, should be interpreted, three simple structure sections are presented here. These sections are diagrammatic in the sense that the exact depth of the Waltham Creek syncline is not known; that too few accurate dips and strikes are available to show all structural details exactly, especially those at a distance from the fault; that while the overlaps shown are all observable within the area, most of them can not be seen along the lines of the sections. That the sections furnish thoroughly possible and reasonably simple interpretations of the structure can nevertheless be easily demonstrated by anyone willing to study Pack and English's map[5] with a little care; or better still, to spend a day or two driving or walking over the beautiful and readily accessible country adjacent to the Waltham Valley Highway.

R. D. Reed

Los Angeles, California
September 17, 1935

SEARCH FOR PALEOZOIC OIL IN WESTERN EUROPE

An interesting development in European exploration is the search for oil and gas in the Upper Carboniferous foreland zone, bordering the front of the Permo-Carboniferous (Variscide) chains in Belgium and in Westfalia. This idea has been stimulated by the similarity of source and reservoir sediments and general geologic and structural conditions with the Appalachian oil and gas belt in Pennsylvania and West Virginia, which extends along the outer front of the very similar Appalachian Mountains, of about the same age as the old European mountains south of the coal fields of Westfalia and Belgium. A more or less similar condition exists in Oklahoma and Texas.

Evidently a search of this nature can only be made at a certain distance from the strongly folded and overthrust mountain front, where regional metamorphism has not unfavorably affected eventual oil deposits. In the zone worked by coal fields the sequence is still devoid of oil and is only moderately gas bearing, while most of these gases apparently originate from the coal seams.

[5] The "Upper Miocene" of Pack and English is now called Pliocene; their "Santa Margarita (?) formation" is now called McLure shale.

Contrary to conditions prevailing in North America, exploration on the European continent is handicapped by the great thickness of Mesozoic, and locally also Tertiary sediments which overlie the Carboniferous, a thickness which reaches 4,000–5,000 feet, making deep drilling imperative and structural subsurface work difficult. On the other hand, certain locally concentrated asphalt deposits and seepages of gas, confirmed by blow-outs of wet gas and even oil showings in several older and not sufficiently deep wells, drilled for coal, are encouraging.

The source beds must be sought in the Lower Carboniferous. They seem at least as promising as those in the Appalachian oil belt of America, notably in the region where these strata are developed in the so-called Culm facies. The source region can scarcely be reached even by modern drilling for petroleum, which now reaches depths of 12,000 feet, but accumulation is expected in sandstones of the coal measures. This seems justified, since petroleum gases permeate even the Cretaceous, and in a few localities on the foreland actual oil has been encountered in coal-measure sandstones.

At present two important test wells are being drilled. One is near Ascheberg, south of Munster in Westfalia, on a subsurface anticline, characterized by a concentration of strong showings (even blow-outs) of wet petroleum gas, including a 30-year old well which, although in very poor condition, still yields gas at 400 pounds pressure. The other well is near the village of Moll, in the Belgian Campine. Both test wells are a considerable distance north of the zone worked by coal mines. The wells are of the most modern type, equipped with machinery which will enable the operators to reach the greatest depths modern technique permits, if such should be required.

Both wells have now reached a depth of 3,000 feet. The one in Belgium has just reached the Carboniferous, the one in Westfalia is drilling in the basal Cretaceous, a short distance off the Paleozoic. Both wells have already shown very considerable gas; in one of them special precautions had to be taken against a threatened blow-out.

Powerful independent capital is back of this research work, which is directed by F. J. G. Vingerhoets, with advice by the writer in a consulting capacity. Several other tests are planned on suitable blocks of leases already assembled. Further geologic details will be given at the International Mining Congress, now (October) assembling in Paris.

W. A. J. M. VAN WATERSCHOOT VAN DER GRACHT

HEERLEN, HOLLAND
October 18, 1935

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REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library and available to members and associates. A list of technical periodicals available for loan to members and associates was published in the *Bulletin*, Vol. 18, No. 9 (September, 1934), pp. 1215–17.

"Summary of the Methods of Exploration for New Oil Fields in Azerbaidjan (Apsheron Peninsula)." By A. A. MELIKOFF. *The Petroleum Industry* (Moscow), Vol. 28, No. 7 (July, 1935), pp. 43–51.

This is a summary of exploration work and of wildcatting on and near the Apsheron Peninsula from 1924 to 1934, inclusive. Three important oil fields were opened in that period of time: Kara-Chukhur, in 1932, and Kala and Lok-Batan in 1933. Also in the same period of time four secondary oil fields and six very small fields were discovered. In all, forty-six prospects have been explored by drilling. In the same period of time, 32,021 square kilometers were surveyed by geological parties and 13,023 square kilometers by geophysical crews.

BASIL B. ZAVOICO

HOUSTON, TEXAS
October 9, 1935

RECENT PUBLICATIONS

ARIZONA

*"Early Cretacic Prospect from Southeastern Arizona," by Charles Keyes. *Pan-American Geologist* (Des Moines, Iowa), Vol. 64, No. 2 (September, 1935), pp. 125–40; 5 figs.

AUSTRIA

*"Der Österreichische Erdölbergbau in Jahre 1934" (The Austrian Petroleum Operations in 1934), *anon.*, with a geological sketch map of the Lower Austrian-Mährischian-Slovakian oil region compiled by H. Vetters. *Petrol. Zeit.* (Vienna), Vol. 31, No. 39 (October 2, 1935), pp. 21–34.

ECUADOR

"Petroleum Situation in Ecuador and Prospects," by G. Sheppard. *Petrol. Times* (London), 34 (1935), pp. 223–24.

EGYPT

*"Geological Observations on the North-West Frontiers of the Anglo-Fgyptian Sudan and the Adjoining Part of the Southern Libyan Desert," by Kenneth Stuart Sandford. *Quar. Jour. Geol. Soc. London*, Vol. 91, Pt. 3 (September 30, 1935), pp. 323–81, Pls. 20–26, Figs. 1–11. Sketch map, cross sections, photomicrographs, areal geology, and a folded areal geology map in colors. (Longmans, Green and Company, Ltd., 39 Paternoster Row, E. C. 4, London.) Price, 7s, 6d.

ETHIOPIA

*"La géologie et les ressources minérales de l'Ethiopie, de la Somalie et de l'Eritrée" (The Geology and Mineral Resources of Ethiopia, Somaliland and Eritria), by F. Blondel. *La Chronique des Mines Coloniales* (Paris), Vol. 4, No. 43 (October 1, 1935), pp. 306–17; 5 figs. including an areal geologic map and a geologic section across the Abai (Blue Nile) Valley. Includes an incomplete bibliography of the years 1870–1934, compiled by G. Stefanini, containing 168 references.

GENERAL

Einführung in die Paläontologie (Introduction to Paleontology), by Hermann Schmidt. Ferdinand Enke, Stuttgart, W., Germany (1935). 256 pp., 466 figs., 47 tables. Lex.-8°. Price, RM. 15; clothbound, RM. 16.80.

Einführung in die Grundlagen der Historischen Geologie. Band 1: Die Ammoniten-, Trilobiten-, and Brachiopodenzeit (Introduction to the Principles of Historical Geology. Vol. 1: Ammonite, Trilobite, and Brachiopod Periods), by R. Wedekind. *Ibid.* (1935). 117 pp., 9 figs., 27 tables. A textbook for schools and universities. Price, kart. RM. 6.50.

*"Petroleum Shortage and Its Alleviation Is Not a Premature Consideration," by L. C. Snider and B. T. Brooks. *Oil Weekly* (Houston), Vol. 79, No. 6 (October 21, 1935), pp. 21–27.

GEOPHYSICS

*"Form, Drift, and Rhythm of the Continents," by William W. Watts. *Pan-American Geologist* (Des Moines, Iowa), Vol. 64, No. 2 (September, 1935), pp. 81–98; Vol. 64, No. 3 (October), pp. 179–84. Presidential address before the British Association for the Advancement of Science, Norwich meeting, September 4, 1934.

*"Radioactivity and Geothermal Gradients," by Justin S. DeLury and H. C. Lane. *Ibid.*, Vol. 64, No. 2, pp. 99–105. Paper read before the Royal Society of Canada, Quebec meeting, May, 1934.

*"Geothermal Gradients," by Justin S. DeLury and J. Spivak. *Ibid.*, Vol. 64, No. 3, pp. 185–92; Figs. 7 and 8. From paper read before the Royal Society of Canada, Quebec meeting, May, 1934.

*"Ultimate Test of Duttonian Isostasy," by Charles Keyes. *Ibid.*, Vol. 64, No. 3, pp. 193–220; 12 figs.

*"Polar Charts for Interpreting Magnetic Anomalies," by Sylvain J. Pirson. *Amer. Inst. Min. Met. Eng.* (New York). Preprint from February, 1936, program (November, 1935), 13 pp., 11 figs.

GERMANY

**Mitteilungen Geol. Staatsinstitut in Hamburg*, Vol. 15 (July, 1935). 151 pp. Contains the following articles in German: "Contributions to the Knowledge of the Alpine Upper Cretaceous No. 2. The Ammonites of Gosan and Flysch in the Northern East Alps," by R. Brinkmann; "Stratigraphy and Paleogeography of Buntsandstone in the Region of the Vosges," by Fritz Forche; "Paleogeographic Research in the Upper Muschelkalk in North and Middle Germany," by Hubert Kleinsorge; "Heavy Mineral Research in the Paleogeography on the Jurassic and Cretaceous in Northwest Germany," by Hermann Deecke.

IRAK

*"The Practical Importance of the Irak Oil Fields," by J. K. Turyn. *Petrol. Zeit.* (Vienna), Vol. 31, No. 39 (October 2, 1935), pp. 5–12; 5 figs., including geological sketch map, political boundary map, and 12 anticlinal sections.

LOUISIANA

*"Bureau of Mines Analyzes Rodessa, Louisiana, Crude Oil," *U. S. Bur. Mines Press Release 3410* (October 24, 1935). 1 mimeog. page.

ROUMANIA

*"Noţiuni de geologia zacamintelor de sare" (Geology of Salt Deposits), by I. P. Voiteşti. *Revista Muzeului Geologic-Mineralogic al Univ. din Cluj*, Vol. V, No. 1 (1933–1934), pp. 1–85; 43 figs., 1 folded map. Institutul de Arte Grafice "Ardealul," Cluj, România. Half-page summary in French. In his lectures on the economic geology of salt deposits, given at l'École Polytechnique de Timişoara in 1929 and 1930, the author discusses the mode of occurrence of salt, its origin, economic importance, and Roumanian and world reserves. The article is illustrated with line drawings and photographs showing many cross sections of salt domes and exposures of rock. A folded map shows the location of salt domes, salines, and formations in the Carpathian region of Roumania.

TENNESSEE

*"Outliers of the Tuscaloosa Formation on the Western Highland Rim of Tennessee," by Kendall E. Born. *Jour. Washington Acad. Sci.* (Washington, D. C.), Vol. 25, No. 5 (May 15, 1935), pp. 222–30; 2 figs.

TEXAS

(CORRECTION OF ITEM IN NOVEMBER)

"The Geology of Texas, Volume II, Structural and Economic Geology." *Univ. Texas Bur. Econ. Geol. Bull. 3401* (Austin, 1935). 900 ± pp., 8 pls., 40 figs., and structural map in colors (scale, 1:1,000,000; contour interval, 500 feet). Cloth. Price, $3.00.

"Structural Map of Texas." *Ibid.* Scale, 1:1,000,000. In colors. Contour interval, 500 feet. Price: paper, $0.50; linen, $1.75; waterproof cloth, $2.00.

ASSOCIATION DIVISION OF PALEONTOLOGY AND MINERALOGY

**Journal of Sedimentary Petrology* (Fort Worth, Texas), Vol. 5, No. 2 (August, 1935).

"The Bottom Deposits of Southern Lake Michigan," by J. L. Hough.

"Structure and Origin of the Phosphorites of the U.S.S.R.," by G. I. Bushinsky.

"A Time Chart for Mechanical Analyses by the Pipette Method," by W. C. Krumbein.

"Petrographic Character of the Pennsylvanian Sandstones in the Ardmore Basin," by Elmer L. Lucas.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 19, NO. 12 (DECEMBER, 1935), PP. 1829-1846, 3 FIGS.

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to J. P. D. Hull, business manager, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

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G. H. Westby, B. B. Weatherby, E. E. Rosaire

Katherine E. Van Winkle Palmer, Ithaca, N. Y.
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Howard C. Warren, Houston, Tex.
J. Boyd Best, Kenneth Dale Owen, G. H. Westby

INTERNATIONAL GEOLOGICAL CONGRESS

The 17th session of the International Geological Congress is scheduled to be held in Moscow, U.S.S.R., in August, 1937. The Organization Committee, Moscow, 10, Sretenka, 8, of which I. M. Goubkin is chairman, A. E. Fersman is general secretary, and S. M. Simkin is scientific secretary, has issued a *Second Circular*, dated September, 1935, stating its conception of the scope of each of the subjects proposed for discussion.[1]

I. THE PROBLEM OF PETROLEUM AND THE PETROLEUM RESOURCES OF THE WORLD

At the preceding sessions of the International Geological Congress the problem of oil and oil deposits has not been discussed in sufficient detail. Only certain aspects of the problem have received attention; thus, at the 16th session in Washington the discussion primarily concerned questions of the geology of oil deposits. No estimate of the world oil reserves has hitherto been given at any of the sessions of the Congress.

The organization committee has passed a resolution for a more complete and detailed discussion of that problem at the 17th session in view of the enormous importance of oil in modern life.

Besides problems concerning the geology of oil deposits, the discussion of which, it is hoped, will arouse the interest of petroleum geologists of all countries, special attention will be called to the problems of the origin of oil and particularly to that of the origin of oil in the North Caucasus fields. The organization committee is of the opinion that a comprehensive study of the problem of the origin of oil in connection with the formation of oil deposits, based on geological and geochemical investigations carried on in different countries, will bring us nearer to the solution of these complicated and important problems of so great a theoretical and practical interest.

The next question to which the organization committee intends to call the attention of the members of the 17th session is that of the estimation of the oil reserves on a worldwide scale.

It should be frankly stated that mankind has no knowledge of the reserves of oil it possesses. No definite figures of oil reserves are available even for individual countries. Even such a country as the United States, which ranks first in oil industry, does not dispose either of firmly established figures of its oil reserves, or of any exact methods for their calculation. The posthumous paper by Dr. David White published in the *Bulletin of the American Association of Petroleum Geologists*, Vol. 19, No. 4 (April, 1935), shows how differing have been the results obtained by American petroleum geologists in estimating the oil reserves of their country.

In the U.S.S.R., calculations made by different experts afforded divergent results. The organization committee takes the opportunity to present this problem for discussion to the petroleum geologists of the world, although it is fully aware of all the difficulties involved.

The problem of calculating the oil reserves of the world falls into two interrelated parts: (1) general methods of calculating industrial and geological reserves of oil, and (2) the estimation of the industrial and geological oil reserves of the world.

In order to obtain more or less uniform data, suitable for comparison and totalling, the organization committee finds it convenient to present its own standpoint concerning the methods of calculating industrial and geological reserves. Having this in view, a special report will be prepared on the subject in several languages and duly sent to different countries. The committee would willingly meet any criticism, suggestions, or

[1] Notice of the *First Circular*, dated January, 1935, was printed in this *Bulletin* of June, 1935, pp. 935–36.

advice, which could be used to develop a more or less uniform method of calculation and to obtain uniformly summarized materials. The committee hopes that petroleum geologists abroad will readily respond to this proposal.

The copies of our report on the methods of calculation are to be mailed in the second half of September, and all suggestions are expected to be received by the end of 1935.

In the beginning of 1936 a scheme of the type method of calculation will be finally elaborated and properly distributed. All material concerning the calculations is expected to be received from all participating countries not later than July 1, 1936, since it should serve as the basis for compiling a report on the industrial and geological oil reserves of the world to be presented to the Congress.

Thus on the subject, "The Problem of Petroleum and Petroleum Resources of the World," it is expected that the following reports will be delivered at the session.

1. On the origin of oil and formation of oil deposits.
2. The origin of oil in the oil fields of the North Caucasus.
3. Methods of calculating industrial and geological oil reserves.
4. The industrial and geological oil reserves of the world.
5. Special reports on the geology of oil deposits and on the prospects of their future development.

II. GEOLOGY OF COAL FIELDS

(See the *Second Circular* for statement.)

III. THE PRE-CAMBRIAN AND THE MINERAL DEPOSITS IN THE REGIONS OF ITS DEVELOPMENT

(See the *Second Circular*.)

IV. PERMIAN SYSTEM AND ITS STRATIGRAPHICAL POSITION

The Permian system is characterized by a rich development of mineral deposits, its complex stratigraphy, diversity of sediments, manifestations of intense tectonic movements and vulcanism and, finally, by great changes in the composition of the fauna and flora.

In putting forward the problem, "The Permian System and Its Stratigraphical Position," for discussion at the session, the organization committee has been guided by the interest now aroused by this particular problem among geologists in a number of countries as well as by the historical rôle played in this respect by the Permian deposits within the territory of the U.S.S.R.

The organization committee considers the main subjects for discussion at the session to be as follows.

1. The problem of the independence of the Permian system, since this problem is solved differently by different geologists.
2. The question of the lower limit of the system, at present the source of considerable controversy, and, accordingly, that of the stratigraphic position of the Uralian.
3. The question of the upper limit of the system within the areas of development of both continental and marine deposits.
4. The main stratigraphic (either twofold or threefold) division of the Permian, the principles of such a division (changes of flora and fauna, diastrophism, volcanic phenomena).
5. Comparative stratigraphy of Permian marine and continental deposits, and correlation of the sections of the type areas of development of the Permian in Europe, Asia, North America, Africa, and Australia.
6. Sedimentation and paleogeography of the Permian.
7. Characteristics of the fauna and flora of the Permian period, and the relative importance of the chief groups of animals and plants for the stratigraphy of the Permian system.

During a special Permian excursion (before the session) the members of the Congress will be able to become acquainted with the Permian and Carboniferous of the Urals, of the Ufa-plateau, and of the Kama and Volga rivers.

An excursion to Central Asia (after the session) will traverse the areas of development of the Permian and Carboniferous deposits of the Tien-Shan and Pamirs. An excursion to Turkestan and Siberia (after the session) will include in its route the areas of development of the continental Upper Paleozoic coal-bearing strata.

V. CORRELATION OF TECTONIC PROCESSES, MAGMATIC FORMATIONS AND ORE DEPOSITS

(See the *Second Circular*.)

VI. TECTONIC AND GEOCHEMICAL PROBLEMS OF ASIA

In putting forward this theme the organization committee is actuated by the fact that due to an enormous accumulation of new data during the last ten years the synthesis of the tectonics of Asia calls for new broad generalizations.

Owing to a great diversity of this material and its dispersion throughout a number of countries, the organization committee considers that the 17th session of the Congress might successfully promote a further extension of our knowledge of the structure of the vast continent of Asia only by means of active collaboration of all geologists interested in this task. The organization committee deems it desirable, therefore, that reports be largely presented to the Congress, dealing with the problems of the tectonics and geochemistry of Asia, both for separate regions and for the whole continent treating the subject in its entirety or in some particular aspect of it.

However, in order to obtain uniformity in the treatment of the general problem, the organization committee begs to draw the attention of those prepared to submit papers on this theme to the desirability of treating the following principal questions.

1. Stratigraphic sections with characteristics of facies and their horizontal and vertical distribution, with annotation of the variation in thickness of synchronous series and statement of all the unconformities.

2. Phenomena of magmatic activity, both of intrusive and effusive type, and their geological sequence.

3. Tectonic forms both in sections and in areal development with a classification according to their age.

4. Movements during the Quaternary period determining the relief of the continent and its contours. At the same time a consideration of seismic characteristics is desirable.

An extensive and profound study of the geology and tectonics of Asia necessarily includes the problems of geochemistry intimately related to them. Geochemistry covers the whole complex of chemical and mineral-forming processes which transport, disperse or concentrate chemical elements, and which for a given area are intimately associated with its tectonic or paleo-geographical history. Without making a detailed review of individual mineral deposits of Asia, the theme should comprise the principal features of their distribution, their relation to the orogenic and magmatic cycles, their correlation with one another, their rôle in the processes of sedimentation, and the general laws of their distribution on the basis of modern geochemistry, crystallo-chemistry, and the science of ore deposits. The committee is of the opinion that this new cycle of ideas will prove highly favorable for the development of our knowledge of ore minerals and non-metallics, and will enable us to establish the general laws of the distribution of elements in the earth's crust, based on facts observed.

In addition to the continent of Asia proper the organization committee includes in the area to be studied: the Urals, the Caucasus, Asia Minor, Syria, and Arabia, in the West; the islands of Java and Borneo, the Philippines, Formosa, and Japan, in the East.

VII. DEPOSITS OF RARE ELEMENTS

(See the *Second Circular.*)

VIII. GEOPHYSICAL METHODS IN GEOLOGY

Under the heading, "Geophysical Methods in Geology," it is intended to sum up all that has been done in the field of applying physical methods of investigation to the solution of geological problems, to indicate the questions immediately arising and the trend of development of this new branch of geological science.

In this connection attention is given in the first place to problems of the absolute age of rocks and of the absolute duration of geological periods, questions which are of paramount importance for the most diverse branches of theoretical and practical geology.

It is desirable, in the first place, that at the session a comparison be drawn of the results of investigations carried out in different countries, and their value estimated; secondly, that the aims of future work be outlined from the material already available; and, thirdly, that the methods for determining the absolute age of rocks be made the subject of an extended discussion.

The second part of the general theme deals with the application of gravimetric methods to the solution of geological problems. Among the questions on which a discussion is desirable the following should be noted

1. Methods of gravimetric work. The most suitable devices for carrying out gravimetric work for geological purposes.

2. The value of gravimetric data for the study of the structure of the portions of the earth's crust nearest to the surface, as well as of the deeper portions.
3. Problems of isostasy.
4. The relation of gravity anomalies to the latest movements of the earth's crust.
5. The application of gravimetry to the exploration of mineral deposits.

The third part of the theme is devoted to the geological value of magnetometric surveying. The following are desirable lines along which work on this subject should proceed.

1. The relation of phenomena of the earth magnetism to the structure of the upper parts of the earth's crust and the methods of treating this problem.
2. The application of magnetometry to the study of mineral deposits.

The fourth part of the theme concerns application of seismic surveying to the solution of geological problems.

In this connection three chief directions of work are suggested.

1. Establishment of the general structure of the earth on the basis of seismometric data.
2. Relation of seismic phenomena to tectonics.
3. Seismic methods in the study of mineral deposits and in economic geology in general.

IX. THE HISTORY OF GEOLOGICAL SCIENCE

Under this heading a number of reports are suggested, dealing with the history of geological science (paleontology, petrography and other branches of geology). The history of geology has so far occupied a backward position in the work of the geologists of the world.

Works on the history of geological science hitherto published in world geological literature are generally confined to a chronological description of facts or to an enumeration of the activity and creative work of individual geologists, or else to a presentation of the history of geological ideas and theories.

In the vast majority of cases, in those works, the development of geology in relation to the development of industry, economy, and politics in a given country is not shown and is not put in connection with the general development of natural sciences.

In putting forward this theme the organization committee expects that a number of reports concerning all the stages of development of geological science since the ancient period will be presented at the session.

The organization committee considers the elaboration of the history of geological science particularly relevant from the end of the 18th century up to the present epoch.

At present great interest is aroused by methodological problems in the field of geology and particularly by geotectonic theories. An analysis of geotectonic theories shows that theories which attempt to establish general laws governing the movements of the earth's crust and to give a picture of the historical development of the earth and its crust, depend, on the one hand, on the state of development reached by geological explorations and the grade of the development of productive forces, and on the other hand, on the most prominent ideas dominating natural sciences and philosophy during the epoch.

The organization committee considers it appropriate to allow an extensive discussion of these problems at the Congress and, in particular, to discuss the problem of geological time, the theory of isostasy, the principle of actualism, etc. The organization committee holds to the opinion that the examination of historical derivations and an exhaustive discussion of these theories will result in a more complete analysis of the present stage of development of geological knowledge and a current estimate of various trends in geological science.

The organization committee requests all those who intend to deliver reports on the above-mentioned subjects to inform the committee in advance of their intended reports, and it requests to be informed of the measures that will be taken both by geological institutions and societies, and by individual geologists in connection with the problems involved.

X. THE OFFICIAL LANGUAGES OF THE 17TH SESSION OF THE INTERNATIONAL GEOLOGICAL CONGRESS

Since the information concerning the official languages of the session published in the *First Circular* has encountered some misunderstanding on the part of some persons and institutions, the organization committee explains that, according to the resolution adopted at the 14th session of the International Geological Congress in Madrid, English,

French, German, Italian, and Spanish will be considered as the official languages of the Congress.

In addition to these languages the organization committee at the 17th session will move that Russian be admitted as an official language of the session of the Congress along with the languages above listed.

Russian, English, and French, as already mentioned in the *First Circular*, are the official languages of the organization committee and are used for the business correspondence of the latter and for the publication of circulars and other materials.

The organization committee will be greatly indebted to geological institutions and societies for bringing the present explanation to the attention of wide geological circles, and also for its publication in geological periodicals.

Persons who for some reason or other have not filled in the application appended to the *First Circular* are requested to fill in the form accompanying the present circular and to forward it to the organization committee.

I. M. GOUBKIN, *president of the committee*
A. E. FERSMAN, *general secretary*

Moscow, U.S.S.R.
September, 1935

I hope to attend the Seventeenth International Geological Congress at Moscow in summer 1937.

I may be able to offer a paper on the following subject

....

I am interested in the following excursions:

	First Choice	Second Choice
Before the Session	....	....
After the Session	....	....

NAME....................................

ADDRESS..................................

....

MID-YEAR MEETING, MEXICO CITY, OCTOBER 16–20, 1935 SAN ANTONIO SECTION ANNUAL MEETING

The American Association of Petroleum Geologists, in conjunction with the San Antonio Geological Society's seventh annual field trip, held its mid-year meeting, October 16–20, 1935, in Mexico City, Mexico. Nearly 350 geologists and ladies attended the convention, coming by automobile, train, and air, chiefly from Texas, Oklahoma, California, Kansas, and Colorado. England, Holland, Louisiana, Michigan, Missouri, New York, and Ohio were also represented. Those who registered were classified as follows: A.A.P.G. members and associates, 118; non-member men, 61; non-member women, 99; total, 278.

The Geological Institute of Mexico was host and its officers and members made every effort to make pleasant, instructive, and entertaining the visit of the geologists, their families, and friends. The reception committee was headed by its president, Sr. Ing. Manuel Santillán, sub-secretary of National Economy and director of the Geological Institute of Mexico. Assisting the president were two former directors of the Institute, Sr. Ing. José G. Aguilera, the dean of all Mexican geologists, and Sr. Ing. Ezequiel Ordoñez,[1] the dean of Mexican petroleum geologists.

FIG. 1.—Group at entrance of Palace of Fine Arts before opening of technical sessions, mid-year meeting, Mexico City, October 16, 1935.

The convention was not only a success in a technical sense, in its papers and field trips, it was a success in inducing scores of American geologists to make their first trip into Mexico. It was a success in bringing about the reunion of many campaigners of the petroleum wars in Mexico of bygone days, notably Sr. Ordoñez, Mr. E. DeGolyer, Mr. William Baker, and many others.

The Regis Hotel was convention headquarters but papers were read in one of the lecture rooms of the white marble palace, the National Theater. The visiting geologists were welcomed at the opening session Wednesday morning by Hon. Sr.D. Cosme Hinojosa, Governor of the Federal District, and replies were made by both president Levorsen of the American Association of Petroleum Geologists, and president Joe Dawson of the San Antonio Geological Society. Two papers were given at this session, one "Synopsis of the Geology of Mexico," by Sr. Ing. Santillán, and one, "The Physiographic Provinces of Mexico," by Sr. Ordoñez.

FIG. 2.—Avenue Juarez, Mexico City, Mexico, showing Regis Hotel on right, convention headquarters.

A trip was arranged for the afternoon to the Department of Archeology of the National Museum and for a brief visit to Chapultepec Castle, the former home of Emperor Maximilian. A reception at home was tendered the visitors by Mr. and Mrs. Henry Norweb, of the United States Embassy staff. In the evening a symphonic orchestral concert was presented in the new National Theater by the Ministry of National Economy. This was unquestionably one of the most enjoyable and impressive features of the convention.

Four papers were given on Thursday morning. "The Areal Geology of Parts of the Rio Grande Border Province of Northeastern Mexico," was given by Wm. G. Kane. "Post-Eocene Stratigraphy of the Mexican Gulf

[1] Sr. Ordoñez is an honorary member of the American Institute of Mining and Metallurgical Engineers, and is credited with the discovery of the Ebano oil field, Tampico district, about 1900, the first oil field in Mexico. Later he was a contemporary and associate of the late Dr. I. C. White in commercial petroleum exploration. He has a wide acquaintanceship with American and European geologists.

Coastal Plain," was read by J. L. Tatum. "Paleogeography of Parts of the Border Province of Mexico Adjacent to West Texas," was presented by Professor L. B. Kellum of the University of Michigan. The fourth and last paper, "The Possibilities for Oil Production from Formations Older Than the Cretaceous in Mexico," by Thomas Calahan, was given by title.

In the afternoon the Indian remains uncovered by Mexican archeologists beneath thick lava flows at San Angel were visited. The age of the flows is now estimated at 4,500 years ago. A brief visit was made to the near-by abandoned convent, "The Desert of the Lions," a remarkably well preserved ruin high up in pine forests above Mexico City. A slight rain and cloudiness partly obscured the excellent exposures of tuffas, alluvio-glacial deposits, and the volcanic rocks of the Sierra de las Cruces.

FIG. 3.—Xochimilco Gardens, showing waterways, flower gardens and tall, nearly branchless trees, characteristic of this area.

The dinner-dance of the convention was held Thursday evening in the Don Quijote Room of the Regis Hotel. It was especially enjoyable in the variety and taste of the entertainment and the music.

Friday the convention delegates and visitors made the all-day trip to Taxco, a Spanish-Indian gold and silver mining settlement on the Pacific slope ranges about 125 miles south of the city on the new Acapulca Highway. Lowell Ridings, American geologist, is operating here a gold and silver mine on practically the same site as one opened by Cortez in 1522. Mr. Ridings was host at luncheon on the grounds and conducted a personal visit to the mine and crushing mill. The ore, consisting of some free silver and mineral compounds, occurs in quartzite along a limestone contact with all the formations tilted to nearly a 45° slope.

The following day, Saturday, was left free for personal visits and many participated in an informal trip to the large silver mines at Pachuca, about 100 miles northeast of the city. Others visited Xochimilco Gardens, the National Palace, the Cathedral, and the shops and markets of the city. A folkloric concert was given in the afternoon by the Geological Institute under direction of Sr. M. L. de Tejada, on the veranda of Chapultepec.

Many of the geologists remained over Sunday for the Aztec Indian demonstration commemorating ancient rites at the Pyramids of Teotihaucan which was kindly postponed from a previous date by the Governor of the Federal District to accommodate convention guests. It was a distinctive and colorful sight, framed in a remarkable setting of Aztec pyramids and temple ruins.

The many geologists who made the trip, especially those who went for the first time, are grateful to the officers and committee of the San Antonio Geological Society whose inspiration and efforts brought the trip to reality. (No persons other than members of the San Antonio Geological Society were permitted to pay any registration fees.) They are appreciative of the coöperation of the officers and many members of the American Association of Petroleum Geologists. The many who shared the hospitality of the seismic camp of the Mexican Gulf Oil Company at Tampacan, near Tamazunchale, wish to thank Mr. S. A. Grogan, geologist in charge at Tampico, and Pat Keely and C. H. Dresbach, in charge at the camp, for their kindness and attentions. They are grateful also to those who colored by hand the large geologic cross-section map of the trip from Laredo to Mexico City (for additional copies of the map write Mr. Adolph Dovre, secretary, San Antonio Geological Society, 602 Milam Building, San Antonio, Texas).

Both American societies and their individual members take this means of expressing their appreciation to the Mexican Geological Institute, its officers and members, for their hospitable welcome and untiring efforts in behalf of the convention, including the persuasion of the Mexican Government to open its Pan American Highway several months ahead of schedule for the benefit of the automobile visitors. The convention marks the first to be held by the American Association of Petroleum Geologists outside the boundaries of the United States and it is a pleasure to report its unqualified success.

J. Brian Eby

Houston, Texas
October 9, 1935

RESOLUTIONS COMMITTEE REPORT, MEXICO CITY MEETING

In recognition of the generous hospitality extended by representatives of Mexico in entertaining the members of the American Association of Petroleum Geologists and the San Antonio Geological Society in Mexico City, October 16–20, 1935, the attending members offer the following.

Be it resolved that we extend our sincere thanks and appreciation to the following individuals and organizations for their efforts in making our meeting a success, and in providing the very unusual entertainment features for our members:

Sr. Ing. Manuel Santillán and the Department of National Economy; the Geological Institute of Mexico, represented by director Manuel Santillán, former directors Sr. Ing. Ezequiel Ordoñez and Sr. Ing. José G. Aguilera, and members Sr. Ing. Hermion Larios, Sr. Ing. Jenaro Gonzalez, Sr. Ing. Teodoro Flores, and Sr. E. C. Borrego; Sr. Cosme Hinojosa, Governor of the Federal District and Mayor of Mexico City; Sr. Lic. Gonzalo Vazquez Vela and the

Department of Education; Sr. Luis Castillo Ledon and the National Museum; Mr. Lowell J. Ridings and General Minerals, Inc.; Mr. Henry Norweb, counsellor of the American Embassy; Sr. M. Zorrilla and Sr. L. Blasquez.

Especially do we commend the local arrangements committee in Mexico, headed by Sr. Ing. Ezequiel Ordoñez, William G. Kane, and Lowell J. Ridings, for their excellent work in planning and carrying out the program and entertainment of our members.

We acknowledge the regrets of Hon. Josephus Daniels that business engagements prevented his presiding at the opening session of our meeting.

Be it resolved further that we thank the Mexican Gulf Oil Corporation and their representatives, Mr. H. M. Neilson and Mr. B. W. Allen, at Tamazunchale, for extending facilities of their camp to our members and friends.

Be it resolved that we extend appreciation to those of our members who contributed papers to our technical program.

Be it resolved further that a copy of these resolutions be sent to each one of the organizations and individuals here listed, and that it be printed in an early number of the *Bulletin* of The American Association of Petroleum Geologists.

Resolutions Committee, CHAS. H. ROW, chairman
L. B. KELLUM, GEORGE H. CLARK

PACIFIC SECTION TWELFTH ANNUAL MEETING LOS ANGELES, NOVEMBER 7–8, 1935

The twelfth annual meeting of the Pacific Section of the Association was held at the Mayfair Hotel, Los Angeles, California, November 7 and 8. Harold W. Hoots, president of the Section, opened the session on Thursday morning in the Rainbow Isle of the headquarters hotel. Seventeen papers of wide geologic and geographic interest composed the technical program arranged by chairman Chester Cassel. Those attending the convention assembled for luncheon each day in the Main Dining Room. The Friday luncheon was followed by the annual business meeting for the election of officers and discussion of Association business. On Friday evening occurred the annual dinner-dance in the Mayfair's Rainbow Isle. President and Mrs. A. Irving Levorsen, of Tulsa, Oklahoma, attended the convention as guests of the Pacific Section. Vice-president Frank A. Morgan, of Los Angeles, is also a national officer of the Association. Past-president William B. Heroy, of New York City, and past secretary-treasurer Monroe G. Cheney, of Coleman, Texas, were present. The total attendance was approximately 200 persons.

The outgoing officers of the Section are: president, Harold W. Hoots, Union Oil Company; and secretary-treasurer, Graham B. Moody, Standard Oil Company of California, San Francisco. The incoming officers, elected at this meeting are: president, Chester Cassel, assistant chief geologist of The Texas Company; and secretary-treasurer, Richard G. Reese, geologist for the Standard Oil Company; both of Los Angeles.

The Pacific Section of the Association Division of Paleontology and Mineralogy held its business meeting on Thursday evening, and after its annual dinner on the Mezzanine of the Mayfair, listened to a technical program under the chairmanship of U. S. Grant, the feature of which was a three-reel

motion picture entitled "The Rôle of the Foraminifera in Existing Oceans," by Earl H. Myers.

ABSTRACTS OF PACIFIC SECTION PAPERS

The papers and abstracts are numbered as on the printed program of the Pacific Section meeting, November 7 and 8, 1935.

1. J. M. Kirby, Geology of the Vacaville-Rumsey Hills Area, Solano, Yolo, and Colusa Counties, California (abstract).

The Vacaville-Rumsey Hills area is a part of the western margin of Sacramento Valley, lying north of Suisun Bay and the confluence of the Sacramento and San Joaquin rivers. The southern part of the area exhibits a stratigraphic section similar to that found along the north flank of Mount Diablo and southward, comprising, as it does, several marine members of the Eocene (including the recently described Capay stage), partially marine Miocene, non-marine Pliocene, and non-marine Pleistocene, in addition to a great thickness of beds belonging to the Chico and Shasta groups. Passing northward, however, the marine Tertiary section is completely removed by progressive overlap of younger upon older formations until, in the extreme northern part, the visible Tertiary section consists only of non-marine upper Pliocene (Tehama formation), resting unconformably on beds well down in the Chico group. Most recent earth movements have affected formations as recent as Middle Pleistocene (Red Bluff formation), indicating that the geologic history of this area is similar to that of the western margin of San Joaquin Valley, and the Coast Ranges in general.

2. Albert Gregersen, The Cuyama Fault (abstract).

This name is suggested for the southeasterly extension of the Nacimiento fault zone (R. D. Reed). The Cuyama fault extends for a distance of more than 60 miles in the area mapped in McKittrick, Santa Ynez, and Mount Pinos quadrangles. Except at the extreme southeastern end, the fault marks the boundary between areas with granitic and Franciscan basement rocks. Between Aliso and Salisbury canyons the fault is obscured by overlying Miocene sediments. These are apparently faulted only slightly but very highly folded along the projected line of the Cuyama fault. The fault developed along the northeast limb of a broad anticline formed against the foreland of Salinia. Faulting probably did not begin until Pleistocene time.

3. R. D. Reed and J. S. Hollister, Paleogeology of Southern California (abstract).

This paper presents a study, illustrated by maps, of the areal geology of Southern California at four different times, including the present. This study suggests some interesting speculations about the structural evolution of the area.

4. Graham B. Moody, Unconformity Exposed in Santa Ana Mountain Foothills (abstract).

An interesting unconformity is exposed in the southwesterly face of the hills east of Tustin, Orange County. Shales of upper Monterey age lie on an erosional surface cut in tilted Vaqueros and Temblor rocks. This unconformity suggests an important break in sedimentation, and is probably equivalent

in time to the one described by Ralph Reed near Hill 885 in the San Joaquin Hills.

5. W. H. COREY, Age of Schist Clastics, Venice District (abstract).

The oil-containing, schist-bearing clastics, on the schist and below the nodular shale of the Venice and Del Rey oil fields, are determined as of Upper Miocene age by fossil mollusks found in cores. Emergence of the area in Vaqueros through Temblor into Upper Miocene time, and conformity between the schist sand and nodular shale, are indicated. They are correlated with Hoots' "basal Modelo graywacke" of Santa Monica Mountains.

6. RICHARD C. KERR, Geological Experiences in the Near East (abstract).

A general account of a trip through the Near East. Special reference is made to the general geology of Irak and Persia.

7. W. P. WOODRING, M. N. BRAMLETTE, and R. M. KLEINPELL, Miocene Stratigraphy and Paleontology of the Palos Verdes Hills, California (abstract). (Given with the permission of the director of the United States Geological Survey.)

The Miocene rocks of the Palos Verdes Hills, or San Pedro Hills, embrace five main lithologic units, consisting, in ascending order, principally of silty shale, cherty shale, phosphatic shale, diatomite, and radiolarian mudstone. The total thickness is about 2,500 feet, and the base is not exposed in the region where the oldest beds crop out. The *Foraminifera* that have been found in each unit indicate that these Miocene beds represent a time range extending from early Middle Miocene (equivalent of Barbat's Gould shale) to the top of the Upper Miocene. These beds overlap northward onto a schist basement of Franciscan (?) rocks, and apparently this northward overlap continues to the Torrance and Playa del Rey oil fields in the southern part of the adjoining Los Angeles Basin. A collection of mollusks from the base of the overlapping late Middle Miocene on the north slope of the hills represents a fauna that in many respects is a new one for the Coast Ranges, as it embraces a number of warm-water genera not heretofore recorded there.

8. B. GUTENBERG, Velocities of Elastic Waves in Rocks of Various Ages and at Various Depths (abstract).

The velocity of elastic waves in rocks increases with the age of the rocks and their depth. In the case of very old rocks, the effect of depth is small; the velocity of the elastic waves in young layers depends more on the depth at which they are than on the age. Consequences of these results as to seismic prospecting and as to theoretical problems are discussed.

9. DONUIL HILLIS, A Colorimetric Method for Determination of Relative Saturation of Oil Sands (abstract).

Water-bearing oil sands between or under saturated oil sands may be recognized with greater certainty in cores when a uniform series of sand samples are treated with measured amounts of solvent and the resulting colors compared with a set of standard samples. A quick method of accomplishing this is explained and several applications are discussed.

10. NORMAN HARDY, Geological Exploration in Borneo (abstract).

The general geology of the Netherlands, India, is briefly described and the distribution of present oil fields outlined. This talk, however, deals

primarily with field-party organization and methods, and includes mention of a few native customs, traditions, and tricks encountered by an unsuspecting (innocent?) geologist.

11. FRANK B. CARTER, The Edison Oil Field (abstract).

The geologic section in this field consists of a series of sediments of Miocene-to-Recent age, which rests on an old tilted and eroded basement complex surface. The series includes the following units: Walker (Oligocene?); Vedder sand (Lower Miocene); Jewett silt (lower Middle Miocene); Freeman tuffite (lower Middle Miocene); Olcese sand (Middle Miocene); Round Mountain silt (Middle Miocene); lower Fruitvale shale (upper Middle Miocene); Fruitvale sand (Upper Miocene); Kern River-Chanac series (Pliocene and Pleistocene); and Quaternary alluvium. The stratigraphy is complicated by a series of overlaps and the presence of at least two major erosional unconformities; also by a tendency of the individual zones to thicken and thin within themselves.

Oil is produced from two distinct zones: (1) Kern River series, and (2) Middle and Lower Miocene. The accumulation of oil in the Miocene rocks is due to overlap of porous sands by impervious organic shales and the folding of these rocks into an anticline plunging sharply to the northwest. Accumulation of oil in the monoclinal Kern River series, while not definitely understood, appears to be due to sealing against a downthrown fault block along the northeast side of the field.

12. A. I. LEVORSEN, The Time of Oil Migration and Accumulation.

13. JOHN GALLOWAY, Accumulation of Oil in the Coalinga District (abstract).

A generalized stratigraphic section is presented and the lithology of each formation briefly described. Seeps and petroliferous sands, productive and otherwise, are enumerated in relation to the stratigraphic section. A typical cross section of North Dome, Kettleman Hills, is shown and the petroliferous zones located stratigraphically. Although no theory concerning the origin of oil is presented, discussion concerning this phase is invited.

14. PARKER D. TRASK, The Proportion of Organic Matter That Has Been Transformed into Oil in the Santa Fe Springs Field.

15. W. A. CLARK, Pressure Phenomena in Oil Fields (abstract).

The paper consists of a review of our ideas of pressures in oil and gas zones. It discusses the source of pressure with application to oil fields; the virgin reservoir, conditions after producing, rate of production and effects with references to specific fields in California; the final possible stages. The paper described briefly use of pressure control in curtailment; Herold's contribution; such use in Texas fields; effect of degrees of curtailment in one California field. The paper closes with mention of a few odd cases of pressure and production with a suggestion of a new pressure source.

16. W. W. VALENTINE, Semitropic Gas Field (abstract).

A description of the Semitropic gas field, Kern County, California, is presented. History of the area shows early recognition of the structural origin of the topographic feature known as Semitropic Ridge. Gas production is coming from sand bodies in the San Joaquin clays of Pleistocene age. Ac-

cumulation is controlled by anticlinal folding with sand lensing as an important factor.

17. J. EDMUND EATON, Miocene of Caliente Range, California.

CODE OF ETHICS OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

OBJECT. The object of this Association is to promote the science of geology, especially as it relates to petroleum and natural gas; to promote the technology of petroleum and natural gas and to encourage improvements in the methods of exploring for and exploiting these substances; to foster the spirit of scientific research amongst its members; to disseminate facts relating to the geology and technology of petroleum and natural gas; to maintain a high standard of professional conduct on the part of its members; and to protect the public from the work of inadequately trained and unscrupulous men posing as petroleum geologists. (Constitution, Article II.)

ARTICLE I. GENERAL PRINCIPLES

SECTION 1. The practice of petroleum geology is a profession. It is the duty of those engaged in it to be guided by the highest standards of professional conduct and to subordinate reward and financial gain thereto.

SEC. 2. The confidence of the public and of the oil industry can be won and held only by the practice of the highest ethical principles.

SEC. 3. Honesty, integrity, fairness, candor, fidelity to trust, inviolability of confidence, and conduct becoming a gentleman are incumbent upon every member of the Association.

ARTICLE II. RELATION OF GEOLOGIST TO PUBLIC AND PROFESSION

SECTION 1. A geologist should avoid and discourage sensational, exaggerated, and unwarranted statements, especially those that might induce participation in unsound enterprises.

SEC. 2. A geologist should not knowingly permit the publication of his reports or maps for the purpose of raising funds without legitimate and sound development in view.

SEC. 3. A geologist may accept for his services in the making of a report an interest in the property reported on, but it is desirable that the report state the fact of the existence of the interest.

SEC. 4. A geologist should not give an opinion or make a report without being as fully informed as might reasonably be expected, considering the purpose for which the information is desired. The opinion or report should make clear the conditions under which it is made.

SEC. 5. A geologist may publish simple and dignified business, professional, or announcement cards, but should not solicit business by other advertisements, or through agents, or by furnishing or inspiring exaggerated newspaper or magazine comment. The most worthy advertisement is a well-merited reputation for professional ability and fidelity. This can not be forced, but must be the outcome of character and conduct.

ARTICLE III. RELATION OF GEOLOGIST TO EMPLOYER

SECTION 1. A geologist should protect, to the fullest extent possible, the interests of his employer so far as consistent with the public welfare and his professional obligations.

SEC. 2. A geologist who finds that his obligations to his employer conflict with his professional obligations should notify his employer of that fact. If the objectionable condition persists, the geologist should sever his connection with his employer.

SEC. 3. A geologist should not allow himself to become or remain identified with any enterprise of questionable character.

SEC. 4. A geologist should make known to his prospective employer any oil or gas interest which he holds in the region of his prospective employment.

SEC. 5. A geologist, while employed, should not directly or indirectly acquire any present or prospective oil or gas interest without the express consent of his employer.

SEC. 6. A geologist retained by one client, should, before accepting engagement by another, notify them of this affiliation, if in his opinion the interests might conflict.

SEC. 7. A geologist who has made an investigation for a client should not, without the client's consent, seek to profit from the economic information thus gained, or report on the same subject for another client, until the original client has had full opportunity to act on the report.

SEC. 8. A geologist should not accept direct or indirect compensation from both buyer and seller, without consent of both parties; or from parties dealing with his employer without the employer's consent.

SEC. 9. A geologist should observe scrupulously the rules, customs, and traditions of his employer as to the use or giving out of information or the acquisition of interests, both while employed and thereafter; and, except as permitted by such rules, customs and traditions or by the consent of the employer he should not seek to profit directly or indirectly from the economic information gained while so employed.

SEC. 10. A geologist employed by a state geological survey should not permit private professional work on the holding of private mineral interests in the state to interfere with his duty to the public or to lessen the confidence of the public in the survey. The preferable course is to avoid such private work and interests.

SEC. 11. A geologist should not divulge information given him in confidence.

ARTICLE IV. RELATION OF GEOLOGIST TO OTHER GEOLOGISTS

SECTION 1. A geologist should not falsely or maliciously attempt to injure the reputation or business of a fellow geologist.

SEC. 2. A geologist should not knowingly compete with a fellow geologist for employment by reducing his customary charge.

SEC. 3. A geologist should give credit for work done to those, including his assistants, to whom credit is due.

ARTICLE V. DUTY TO THIS ASSOCIATION

SECTION 1. Every member of the Association should aid in preventing the election to membership of those who lack moral character or the required education and experience.

SEC. 2. A member of this Association who has definite evidence of the violation of the established principles of professional ethics by another should report the facts to the executive committee.

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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 19, NO. 12 (DECEMBER, 1935), P. 1847

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

ROLF ENGLEMAN is employed by the Carter Oil Company with headquarters at McAlester, Oklahoma.

The Geophysical Instrument Company, 817 G Street, N. W., Washington, D. C., has taken over the work of constructing and selling geophysical apparatus formerly carried on under the name of Shelley Krasnow.

BARNUM BROWN, of the American Museum of Natural History, New York, lectured on "One Hundred Forty Million Years of Dinosaurs," at Tulsa, Oklahoma, November 6, under the auspices of the Tulsa Town Club and the Tulsa Geological Society.

FRANK GOUIN, of Duncan, Oklahoma, spoke on "Deeper Producing Possibilities in the Ardmore Basin, Oklahoma," before the Tulsa chapter of the American Petroleum Institute, November 6.

The new officers of the Shawnee Geological Society, Shawnee, Oklahoma, are: president, W. D. HENDERSON, of the Stanolind Oil and Gas Company; vice-president, W. H. WYNN, of the Sinclair-Prairie Oil and Gas Company; and secretary-treasurer, H. W. O'KEEFFE, of the Phillips Petroleum Company.

The East Texas Geological Society, Tyler, Texas, has elected the following officers for the coming year: president, H. J. MCLELLAN, Humble Oil and Refining Company; vice-president, J. W. KISLING, JR., Amerada Petroleum Corporation; and secretary-treasurer, GEORGE W. PIRTLE, Hudnall and Pirtle.

LOWELL J. RIDINGS is president of General Minerals, Inc., S. A., with offices at Mexico City and mining operations at Taxco, Mexico.

The Mayo Hotel has been selected as convention headquarters for the twenty-first annual meeting of the Association, March 19, 20, and 21, 1936, at Tulsa, Oklahoma. FRANK RINKER CLARK, Marathon Oil Company, is general chairman of the committee on arrangements; W. B. WILSON, Gypsy Oil Company, is chairman of the committee on entertainment, and IRA H. CRAM is chairman of the committee on the technical program. Send in titles and abstracts of the papers you will present.

SYLVAN SHALE IN JOHNS VALLEY

CORRECTION

In the geological note, "Sylvan Shale in Johns Valley," in the November *Bulletin*, page 1694, two errors were printed for which the undersigned desires to absolve the Oklahoma Geological Survey of all responsibility. "John's" should be *Johns* (without an apostrophe) and "*Diplodocus*" should be *Diplograptus*.

J. P. D. HULL

INDEX TO VOLUME 19